POWER SYSTEM RELIABILITY CONSIDERATION

A THESIS
SUBMITTED TO THE COLLEGE OF ENGINEERING
OF UNIVERSITY OF BAGHDAD
IN PARTIAL FULFULLMENT OF REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE
IN ELECTRICAL ENGINEERING

BY
MOHAMMED TOWFIK LAZIM

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ABSTRACT

Power system reliability considerations are very important factors in planning of generating, transmitting and distributing facilities.

A good power system must operate at an adequate level of reliability for its main three parts, generation, transmission and distribution. The work in this thesis deals with these main parts. The first part deals with the generating system reliability evaluation theories and their application to a practical system such as Iraqi generating system.

The second part covered an investigation into the failure occurs on the transmission system facilities in Iraq and a statistical correlation studies between the meteorological phenomena and these failures, Also an estimation of line and equipments failure and repairing rate with availabilities and outage times evaluations.

The Morkov exact technique is applied to a typical lines in Iraq and examined by the frequency and duration method.

The third part of this work deals with the distribution system reliability evaluation theories and their application to a practical system. A general formula for simplified and fast computation of the ring system

feeders reliabilities and several practical switch gears configurations is developed.

It should be emphasized that this is only one step which is to be extended by further researchers in order to study in more details the extension and reserve requirements for the generating system, failures on the generating facilities and modification of the developed ring system formula to be more general for another switch gears configurations.

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مـــــع تحياتـــي العميقـــة لبلدي الحبيـــب

ومـــع الاحترام الابـوي الذي احملـــــــــه

اهـدي نتاجي هذا الى السيد وزير الدفـــــاع

العـــراقـــي المحتـــرم

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INTRODUCTION

The reliability studies in planning of a power system became as important factor as economics, where increased attention is directed for supplying industrial consumers with their needs of continuous and reliable supply.

The interest in evaluation of quantitative reliability of a system is a present day problem. Many techniques and methods have been developed in recent years, but all depend on the probability and event prediction styles. These techniques are applied to the main parts of a power system which are the geneamating, transmission and distribution. In order to evaluate the reliability of each component, and the system in general, the reliability studies can be classified into the following three main parts: -

1. Generating system reliability evaluation.
2. Transmission system reliability evaluation.
3. Distribution system reliability evaluation.

The first part of this thesis deals with generating system reliability evaluation. Many techniques and methods have been developed to evaluate the reliability of a given generating system which include both the static and spinning capacity reserve evaluation. The

most accurate method which is the loss of load probability approach is discussed in this thesis and is applied to evaluate the risk level and to check reserve position of Iraqi generating system.

Data from Iraq N.E.A for load variations and generating equipment with statistical information is analysed and studied using the digital computer which is available in the computer center, college of engineering, Baghdad University.

A computer program is developed for scheme extension of any given system using calabrese technique for static reserve evaluation. This program is applied for Iraqi N.E.A generating system up to the year 1990.

The second part of this thesis deals with the transmission system reliability evaluation. The most accurate methods which are the Markovian technique, as well as the frequency and duration method are examined and applied to a practical system such as that of the N.E.A Iraqi Grid.

Starting from the basic statistical information and troubles data together with meteorological informations, the reliability indices for all 132 KV transmission facilities in Iraq have been evaluated using basic reliability principles.

Data from Iraq N.E.A for the period Jan-1969 to Dec-1973 has been analysed using the available 1130 IBM Computer.

The Markov approach and the approximate method have been applied also to evaluate the reliability measures with special consideration to the two-state fluctuating environment for two typical lines in Iraq which are connecting Nassiriya- Shuaiba Sub-stations.

The third part of this thesis is concerned with the distribution systems and switchgear facilities study. The general probabilistic approach which is based on probability theory and Boolean algebra is used to find a general formula for ring system feeders reliability estimation. This formula is also applied to simple switchgear configurations, such as the double busbar double breaker, and breaker and a half schemes.

Many statistical and numerical methods and techniques has been made use of; such as the least square, difference tables, Newton forward and back word formula together with the available functions and subroutines for matrix inversion, curve fittings and factorial problems which are available in the computer storage disks, cores, and library.

PART I

GENERATING SYSTEM RELIABILITY EVALUATION

CHAPTER I

Historical Investigations and Methods For Generating System Reliability Evaluation

1.1 General

The generating System reliability evaluation is very important factor in power system reliability considerations. This field can be considered to take two basic forms which are :

a. The static reserve: the installed capacity which must be planned in advance of the system requirements. The overhaul of generating equipment, the outages that are not planned, or scheduled, and load growth in excess of estimates, would also effect the static reserve requirements.

b. The spinning reserve: the capacity which must be available at all times; to meet load changes on the system, or any instantaneus forced outages, without effecting the system frequency.

The application of probability methods to the static capacity problem provide an analytical basis for capacity planning, and the interest in the application of this techniques became evident as early as 1933 and extended to cover partial or complete integration of systems.

The numerical reliability criteria for generating systems was suggested first by Deen[1] who reported on interruption frequency and duration measures. The probability and frequency measures for generating systems were dealt with by Lyman[2] and Smith[3]. Cone[4] introduced a method for generating system reliability evaluation. This method was based on the outage risk of overlapping transmission and generation.

Repairable system with definite restoring time was modeled by Use of the fameous Markov chain with discrete and continuous process technique.

Barlow and Hunter[5] gave a brief analysis of such approach. The state space concept and its application to reliability evaluation of power system was introduced by De Sieno and Stine[6], while the application of Boolean algebra on reliability evaluation problems was developed by Egly etal[7]. A number of papers had been published on this subject and the proposed methods fall into the following four catagories:

1. The loss of load probability method.
2. The loss of energy probability method.
3. The simulation method, or Montecarlo technique.
4. The frequency and duration approach.

The loss of load probability, and the frequency and duration methods are the most well known and usable techniques for generating system reliability evaluation. These two techniques are based on the criteria that the probability of encountering the various levels of generating capacity inadequency for a given system are determined as the indices of reliability of the generation model and load characteristic of the system are known.

The loss of energy probability method is similar to the loss of load approach but utilises the ratio of the expected energy curtailed due to generating unit forced outages to the total energy required by the system.

The simulation technique is based on developing the capacity model and also a load model from a given historical statistical data by using Montecarlo technique.

The loss of load probability, and frequency and duration methods will be discussed in more details in the following sections.

1.2 The Loss of Load Probability Method:[8]

For determining the generating system reliability; two system parameters are normaly utilized. These parameters are load characteristics and system generating facilities.

The application of the loss of load probability method to generating system reliability evaluation involves three basic steps:

a. A probabilistic table is Constructed to describe the capacity outage probability of the system. This is referred to as the " capacity outage probability table" and can be developed by using the binomial expansion and basic probability concepts.

b. The system load characteristic which gives the informations about the daily load curve of the system.

c. The loss of generation probability table and the system load characteristic are merged to give a loss of load probability and many details about system deficiency or system curtailment due to a given load.

1.2.1 The Capacity Outage Probability Table

The basic probability Concepts are used to obtain the capacity outage probability table. The binomial expansion is used in practice to give this table by assuming that each unit in the system exist either in an up (full capability), or in Down(Zero capability) States. Then if over a long period of time (T) a unit has been unavailable because of forced outage for a time(t), the outage rate of this unit is defined as

$$q = \frac{t}{T}$$

and hence the availability of this unit is $p = 1 - q$ where $p + q = 1$.

This binary state of the unit leads to use the binomial expansion of (n) similar units operating

in a given system, i.e each unit in the system having identical p and q probabilities. Hence the probability for all possible combinations of unit outages are given by the binomial expansion:

$$(p+q)^n = p^n + np^{n-1}q + \frac{n(n-1)}{1 \times 2} p^{n-2} q^2 + \ldots\ldots$$

$$+ \frac{n!}{r!(n-r)!} p^{n-r} q^r + \ldots\ldots\ldots\ldots + q^n \qquad \ldots\ldots(1.1)$$

where r = Number of units out of service at the same time.

hence the probability of (r) units outage from(n) units is given by : -

$$P_n^r = \frac{n!}{r!(n-r)!} p^{n-r} q^r \qquad \ldots\ldots(1.2)$$

The application of this formula is illustrated in the following simple example:

Assume that 80 MW(megwatt) system is composed of two units, one rated 30 MW and another rated 50MW. Both units will be assumed to have a forced outage rate of 0.02.

There are four states in which this system could exist,and for each of these states that exact probability of occurrence can be determined as shown in table 1.

Table I

Determination of probability of occurrence of capacity outages

State Number	Capacity on Outage (MW)	Probability of Occurrence, percent
1	0	(0.98)x(0.98)= 0.9604
2	30	(0.98)x(0.02)= 0.0196
3	50	(0.02)x(0.98)= 0.0196
4	80	(0.02)x(0.02)= 0.0004
		1.0000

A cumulative table of capacity outage may be constructed from the above table showing the probability of lossing capacity equal to or exceeding various amounts, Table II shows how this is carried out.

Table II

Cumulative Outage

Amount(MW)	Probability of Losing
80 or more	0.0004
50 or more	0.0004 + 0.0196 = 0.020
30 or more	0.0004+0.0196+0.0196=0.0396
Zero or more	0.0004+0.0196+0.0196+0.9604=1.000

The previous two tables may be combined as in Table III to give a new table giving all loss of generation probabilities.

Table III

Combination of Tables I and II

Capacity on outage(MW)	Probability of Occurrence	Probability of Capacity Outage equal to Amount shown or more
0	0.9604	1.0000
30	0.01960	0.0396
50	0.01960	0.0200
80	0.0004	0.0004

The cumulative probability values decrease as the capacity on outage increases. This of course is generally true for the exact probability of occurrence table. Theoretically the capacity outage probability table incorporates all the system capacity. But in practice, the table is usually terminated when the cumulative outage probability for any capacity level is less than 10^{-8}. There is virtually no difference in the end result in curtailing the table at this value (12).

1.2.2 The " Calabrese" Computing Technique

The loss of generation table has been described in the previous section while the load characteristics of the system can be obtained from the daily peak load duration curves for a given period under studies.

In this technique; the system outage probability table and the load characteristic are combined to give the expected risk of loss of load. A typical system load capacity relationship is shown in fig(1.1).

Referring to the figure itself;if the capacity outage Ck is less than the reserve magnitude R, then there will be no contribution to the system expected loss of load, while any outage capacity in excess of the reserve will lead to a loss of occurrences. And since these events are randomly behaving, so the mean value or the outage value of occurrence can be obtained by using the expectation theorem.

1.2.2.1 Mathmatical Background of The Technique

Suppose X is a simple random Variable which takes any value in the finite set $T = x_1, x_2, .. x_n$, with probabilities $P_i = P(x = x_i) = P_x(x_i)$ for each value of i=1,2,...,n. Then the probability weighted average

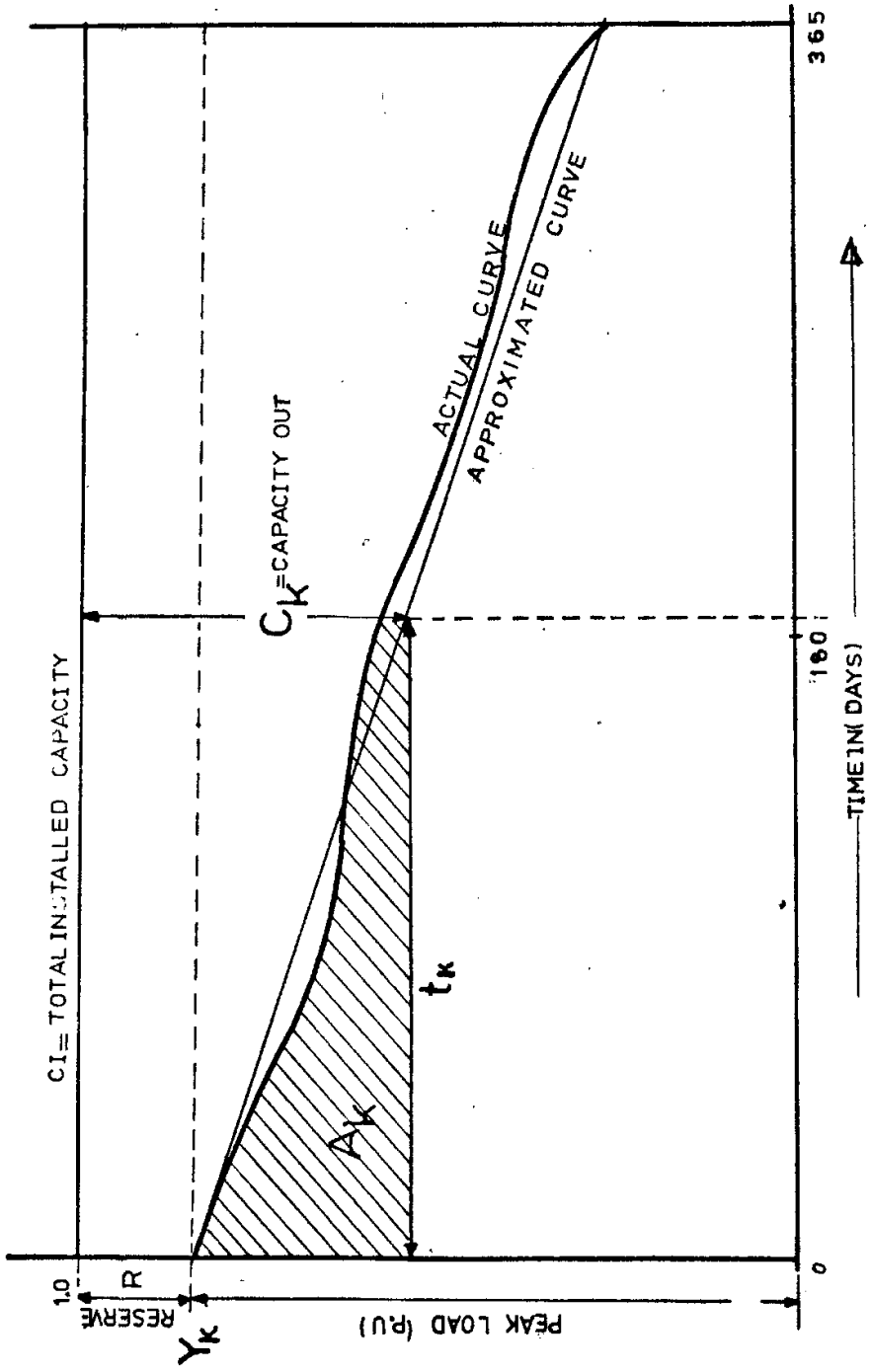


Fig.(1.1): peak Laod Duration Curve

average is given by

$$E_{(x)} = \sum_{i=1}^{n} x_i \, P(x = x_i)$$

$$= \sum_{i=1}^{n} x_i \, P_x(x_i)$$

$$= \sum_{i=1}^{n} x_i \, P_i \qquad \ldots\ldots(1.4)$$

Now if this random variable is time i.e $x = t$, then equation (1.4) can be written as follows:

$$E(t) = \sum_{i=1}^{n} t_i P_i \text{ (Time Units)} \ldots(1.5)$$

This equation is used to evaluate the risk level for any given system provided that the generating and load models are known as will be seen from the following subsections.

1.2.2.2 The Technique Assumptions

As any other techniques the loss of load or calabrese technique has its own assumptions, these are as follows:

1. The annual load duration curve is assumed linear.
2. All units are identical with size and outage rates, and of the same type, i.e the system is uniform.
3. No maintenance outages are assumed, and no problems due overload are considered.
4. The forced outage rates of a unit system generator is defined by the AIEE and investigated by various Commities and electricity generating boards. as,(number of days of forced out/number of days of operation + number of days of forced out).

The average value for this outage rate is about 0.01 and the national average rate is very close to 0.02 . For developing countries(such as Iraq) no value of outages have been found in literature [9] . Nevertheless, it is reasonable to assume that the outage rate, q, for these countries is higher.

This value is taken at 0.02-0.05, but in this analysis and calculations an average rate of 0.02 is considered.

5. The total installed capacity of the system is assumed as a base (unity), or 100% .
6. The machines operation is random and has a binary state model either operation or fail to operate, with probabilities P = 1-q and q respectively.

The variation of availability with the number of generators in a system is shown in fig.(1.2).

1.2.2.3 The Loss of Load probability Equation

As it has been mentioned before that a loss of generating capacity will not give rise to loss of load probability, hence one must differentiate between the term " capacity out" and " loss of load" .

The loss of load probability can occur if and only if the generating capacity remaining in service is small than the value of the load level in the system. Therefore any capacity loss greater than the available reserve will give rise to

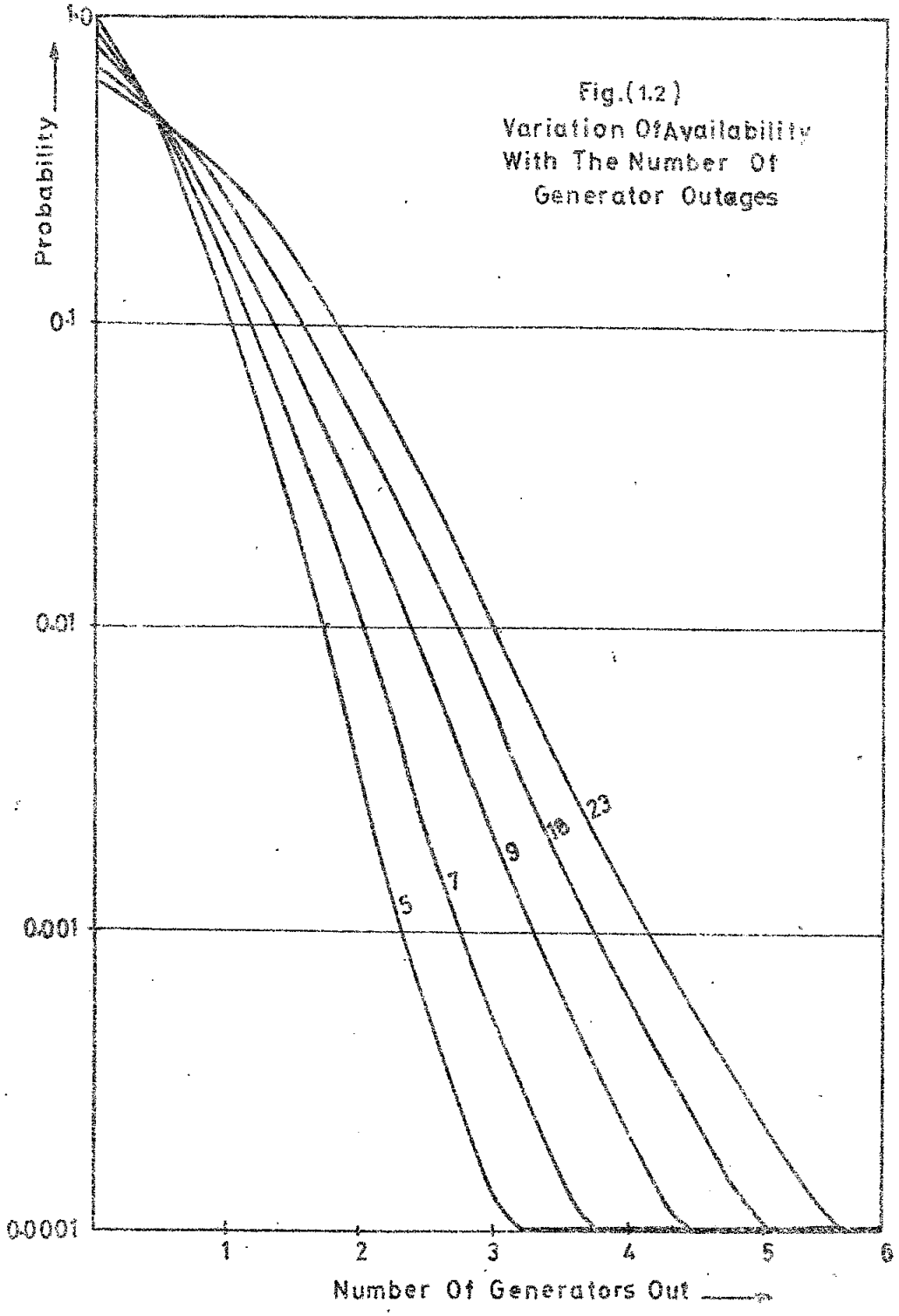


Fig.(1.2)
Variation Of Availability
With The Number Of
Generator Outages

a probability of loss of load.

Referring to fig.(1.1); for outages less than the value R indicated in the diagram, there will always remain sufficient capacity to meet the load. For an outage(C_K) there will not be sufficient capacity to meet the load for time t_K. The loss of load probability correspond to this particular outage (C_K) is equal to the product $P_K t_K$, where P_K is the probability that an outage of exactly(C_K) would occur, and t_K is the time for which such an outage would occasionally, cause loss of load. When all possible values (C_K) are considered, the total expected load loss is given by :

$$E(t) = \sum_{K=1}^{n} P_K t_K \qquad \text{time Units....(1.6)}$$

Equation(1.6) is known as the " loss of load probability equation". It is used for the determination of generating reliability indices and study of the risk level for any given system.

1.3 The Frequency and Duration Method[10],[11]

This method provides more reliability indices and more physical significance than the loss of load probability approach, because it does not only take the peak load of the system as an absolute value but it also take its duration and distribution during a certain time interval.

The frequency and duration method which is based on the frequency index style provides more informations about generating system capacity outage states; and the transition from one state to another.

The application of the frequency and duration approach to the problem of determining the generating capacity reliabilities involves three basic steps.

a. A model giving the probability of loss of generation is developed first, this is referred as the " Generating System Model".

b. A Model describing the probabilistic nature of peak loads of the system or " Demand model" .

c. The above two models are then merged to give "Generating Reserve Mode" of the system.

It is to be noted that the generating system model in this method is similar to the capacity outage probability table developed in the loss of load probability approach with some additional informations.

1.3.1 The Generating System Model(GSM)

As far as the steady state probabilities of exact and Cumulative capacity outages are concerned the GSM model includes the frequency and hence the mean time of encountering these levels or conditions.

The information and data required to develop the GSM are the availabilities and mean durations for each condition of generating capability for all the units in the system.

Using the state space concept, each unit has been assumed to exist either in an up (full capability)or in a down (zero capability) state. This binary model is applied to each unit in the system and its average behaviour can be represented as shown in fig.(1.3). where

u = The mean up time of unit.

r = The mean down time of unit.

The mean duration time r and u are assumed to be constant, and the reciprocal of mean up time u is the average failure rate ($\lambda = \frac{1}{u}$) which is the rate with which a unit would transit from up state to down state. Similarly, the reciprocal of the mean down time ($\mu = 1/r$) is the rate with which a Unit would transit from the down state to the up state, this binary model is illustrated simply in fig(1.4).

The steady state probability of a unit being in the up state is the availability of the unit itself and designated by (A). Hence the unavailability of the unit is ($\bar{A}$) . So that : -

$$A = \frac{u}{u + r} = \frac{\mu}{\mu + \lambda} \qquad \ldots\ldots(1.7)$$

$$\bar{A} = \frac{r}{u + r} = \frac{\lambda}{\mu + \lambda} \qquad \ldots\ldots(1.8)$$

The basic principle of the frequency and duration approach is given by the following definitions and relationships;

f = The frequency of encountering a state A

= A . λ

= (Steady State probability of being in the state)x (Rate of departure from that state) ...(1.9) .

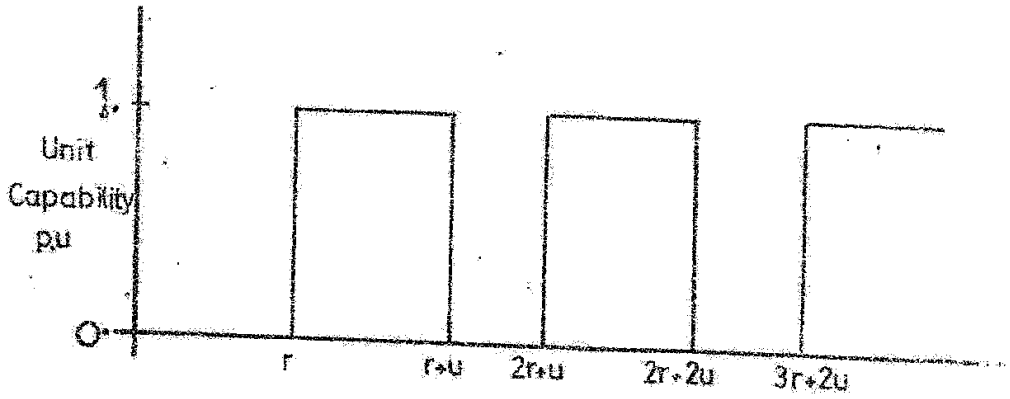


Fig.(1.3): Average Behaviour
Of Unit Capability

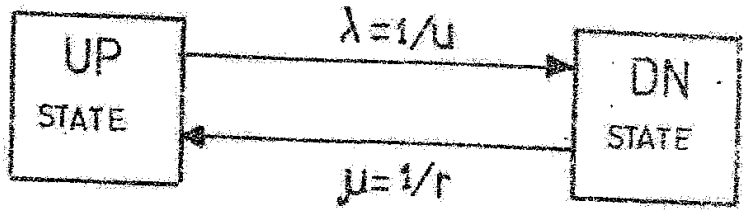


Fig.(1.4): Binary Model Or Two State
Transition Diagram Of a Unit

or

$$f = \bar{A} \cdot \mu$$

= (Steady state probability of not being in the state) x (Rate of entery into that state)...(1.10)

Hence the availability and frequency of encountering the exact state can be obtained by using eq.(1.7 - 10).

1.3.1.1 Cumulative Capacity Outage States

Generally the calculation of the frequency of encountering exact capacity state is not too much difficult. However it is more interesting to determine the availability and frequency of the cumulative capacity outage states; i.e those states with capacity on outage equall to or greater than a given value.

The availability and frequency can be obtained by repeated application of the following relations to the capacity outage states.

Arranging in the ascending order of outage, and referring to fig (1.5), thus : -

$$A_{n-1} = A_n + A_K \qquad \ldots\ldots(1.11)$$

and Frequency

$$f_{n-1} = f_n - A_k \cdot \lambda_{-k} + A_k \cdot \lambda_{+k} \qquad \ldots(1.12)$$

More Capacity on Outage	Exact Capacity Outage		Cumulative Capacity Out		Less Capacity in
↓	C_1	$\leqslant$	C_1		↓
	C_2	$\leqslant$	C_2		
	C_3	$\leqslant$	C_3		
	.		.		
	.		.		
	.		.		
	C_k	$\leqslant$	C_{n-1}	$(K=n-1)$	
	C_n	$\leqslant$	C_n		
	.		.		
	.		.		
	.		.		
	C_N	$\leqslant$	C_N		

$$C_n = CI - C_n$$

where

CI = Capacity installed.

C_n = Capacity in

hence $C_n \geqslant CI - C_n$

or $C_n \leqslant C_n$

Fig.(1.5) Relation ship of Cumulative Capacity outage to Exact Capacity outage Arranged in Ascending order.

where

A_{n-1}, f_{n-1} = Availability and frequency of (n-1) th Cumulative Capacity outage.

A_K = Availability of the state being added.

λ_{+K} = Rate of transition from state K to states in which more capacity is available.

λ_{-K} = Rate of transition from state K to state in which less capacity is available.

Now, when constructing the generating system model for any system, the outage capacity probability table may contain a number of similar or identical capacity outage.

These identical capacity outages are grouped together with the frequency of encountering its state in accordance to the following relation ships

Availability

$$A_K = \sum_{i=1}^{N} A_j \qquad \ldots\ldots(1.13)$$

Frequency

$$f_K = \sum_{j=1}^{N} f_j \qquad \ldots\ldots(1.14)$$

Subscript "j" refers to those states having the same capacity in outage, and (K) indicates the grouped or merged states.

1.3.2 Load Model Representation[12]

The sequence of daily peak loads is assumed to be a Stationary, random process. The load model represents the daily load cycle as a sequence of peak loads L_i, each of mean duration "e" days interspersed with periods averaging (1-e) days of a fixed light load level L_0. The sequence of peak loads is random as shown in figure (1.6) on the following page.

The required parameters associated with the load model are as follows.

Load states of high level

Number of load levels considered — N

Description of the load level, MW — $L_i, i=1,2,\ldots,N$

Number of occurrence of L_i — $n_i, i=1,2,\ldots,N$

Interval length, Days — $D = \sum_{i=1}^{N} n_i$

Expected duration of the peak probability of L_i — $e < 1$, $P_i = \dfrac{n_i e}{D}$

Transition rate to a greater load — $\lambda_{-L_i} = 0$

Transition rate to a lesser load — $\lambda_{-L_i} = 1/e$

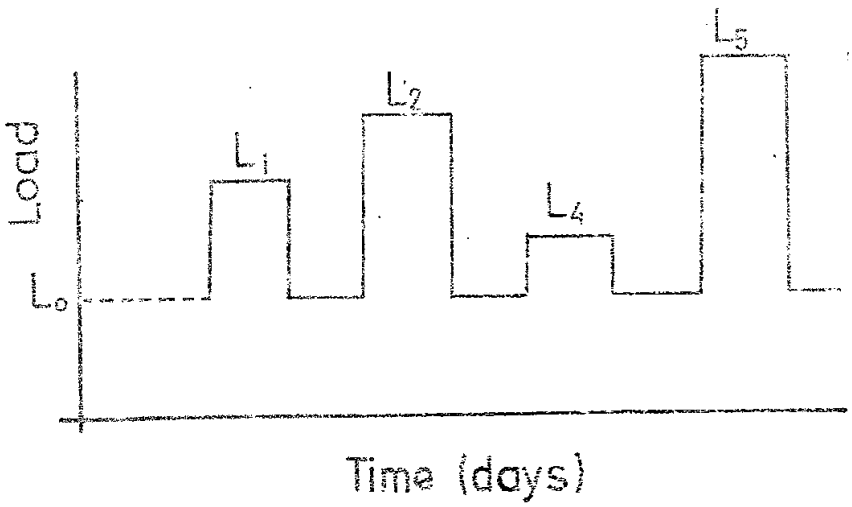


Fig.(1.6a): Basic Load Model

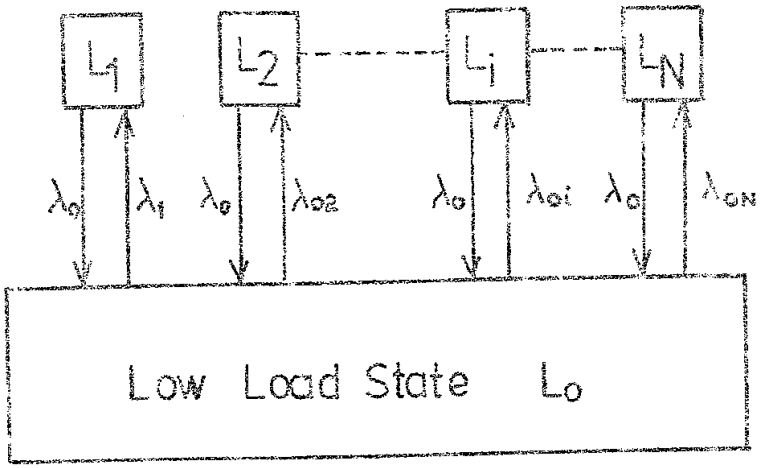


Fig.(1.6b) : State Transition Diagram
Of The Basic Load Model

Frequency of occurrence of L_i $\quad f_i = n_i / D$

For the low load period :

Load State of light load $\quad L_o$

probability $\quad P_o = 1-e$

Transition rates $\quad \lambda_{L_o} = C$

$\quad \lambda_{L_o} = 1/(1-e)$

frequency $\quad f_o = 1$

The load model as shown in figure (1.6a) assumes that the load returns to the light load level L_o each time prior to moving to a new peak value L_i. An alternative model in which the load level moves from one state to any other is shown in figure (1.6 b).

1.3.3 Cambination of the Load and Capacity Models (Reserve Margin)

A capacity margin probability table can be obtained by Combining the capacity and load models as follows.

A margin state m_K is the combination of the load state L_i and the capacity state C_n where :

$$m_K = C_n - L_i$$

The rates of departure associated with m_K are as follows: :

$$\lambda_{+ m} = \lambda_{+ C} + \lambda_{- L}$$

$$\lambda_{- m} = \lambda_{- C} + \lambda_{+ L}$$

The probability of occurrence of two or more events in a single small increment of time is assumed to be negligible. The transition from one margin state to another can be made by a change in load or a change in capacity but not by both simultaneously.

The upward margin transition rate λ_{+m} is, therefore, the Summation of the upward capacity transition rate and the downward load transition rate. The opposite is true for λ_{-m}, the downward margin transition rate.

The availability of the margin state is the product of the capacity state and load state availabilities.

Probability $P_K = P_n \cdot P_i$

The frequency of encountering the margin state m_K is the product of the steady state probability of the margin state and the summation of the rates of departure from the state:

Frequency $f_K = P_K (\lambda_{+K} + \lambda_{-K})$.

Having obtained the individual probabilities and frequencies of the margin states, the cumulative values can be obtained in a similar manner to that used in the capacity model.

1.3.4 Characteristics of Frequency and Duration Method:

As it has been shown from previous discussion that the frequency and duration approach posseses a Certain physical significances which does not exist in the loss of load probability method.

The application of the state space concepts and recursive technique together with the renewel theory [13] provided more details about the availabilities and frequencies of encountering a particular State and the transition from one state to another.

The exposure factor which is a parameter that gives more details about the peak load durations cannot be found in the loss of load probability technique.

CHAPTER 2

IRAQI GENERATING SYSTEM RELIABILITY CONSIDERATIONS

2.1 Introduction

Calculations of generating system capacity reserve requirements and availabilities provide usefull information for planning system generating requirements for the future. Among the factor which establish the installed generating capacity required in future is the amount of reserve which will be needed. This reserve capacity will depend upon the load to be served, the output capabilities and the outage factors of the individual components of the supply, and the index of reliability desired. If larger generating units are to be installed, larger reserve will results. Hence, the timing for installation of new generating capacity will, to some extent, be dependent upon the total system reserve requirements.

The study in this chapter is made to use the probability methods for reliability evaluation and to express the reserve requirements for Iraqi generating system, and it can be summerized into the following points:

1. Use of statistical methods to study the daily peak load variation of Iraqi system during one year, and to establish a suitable load model for this period of

study, with special regard to the load forecasting of the system itself.

2. Determination by probability methods the expected frequency and duration of forced outages of generating capacity, and to find a generating system model.

3. Establishment of criteria of reliability on the basis of frequency of emergencies which the system must be able to meet without voltage reduction or loss of load.

4. Development of a computer programme for obtaining the new generating system model after the addition of new unit to the system.

5. Use of " Calabrese" or loss of load probability method to express or determine the static reserve requirements for total Iraqi generating system up to the year 1990.

The outage rates used in this study for the various types of equipments are based on the national data and reports of developed countries[9]. The mean failure rate of each unit is assumed to be 0.02 failures per day and thus the availability is 0.98. The standard risk level for this study is assumed to be 1.5 days/year, this level is reasonable for reliability studies in developed countries[19].

All necessary calculations and numerical solutions which aid this study are done using the IBM 1130 digital

computer. Although this computer has a limitted capacity and relatively low speed of calculation, it performs all calculations and numerical solution efficiently.

2.2 Iraqi System Load Characteristics

Before starting to evaluate the reliability indices and comparing the static reserve position for different years for the Iraqi generating system, the nature of the peak load, the load fore casts, and load duration characteristics must be known. In the following studies, data of the total Iraqi peak load variations obtained from N.E.A dispatching center, are analysed in order to find the shape of daily peak load variation and to obtain a constant load characteristics for the total system.

2.2.1 The Annual peak load variation

The data of total Iraqi daily peak load variation is now available over the year 1972. The annual peak load variation can be expressed by a general function(polynomial) by using statistical methods and numerical Techniques The method of least square of error for curve fittings[14] is adopted here, as a choice, in order to obtain the polynomial representation of the daily peak load variation for the total system. The general expression for the polynomial function is given by :

$$V(y) = a_0 + a_1x + a_2x^2 + a_3x^3 + \ldots + a_nx^n \ldots (2.1)$$

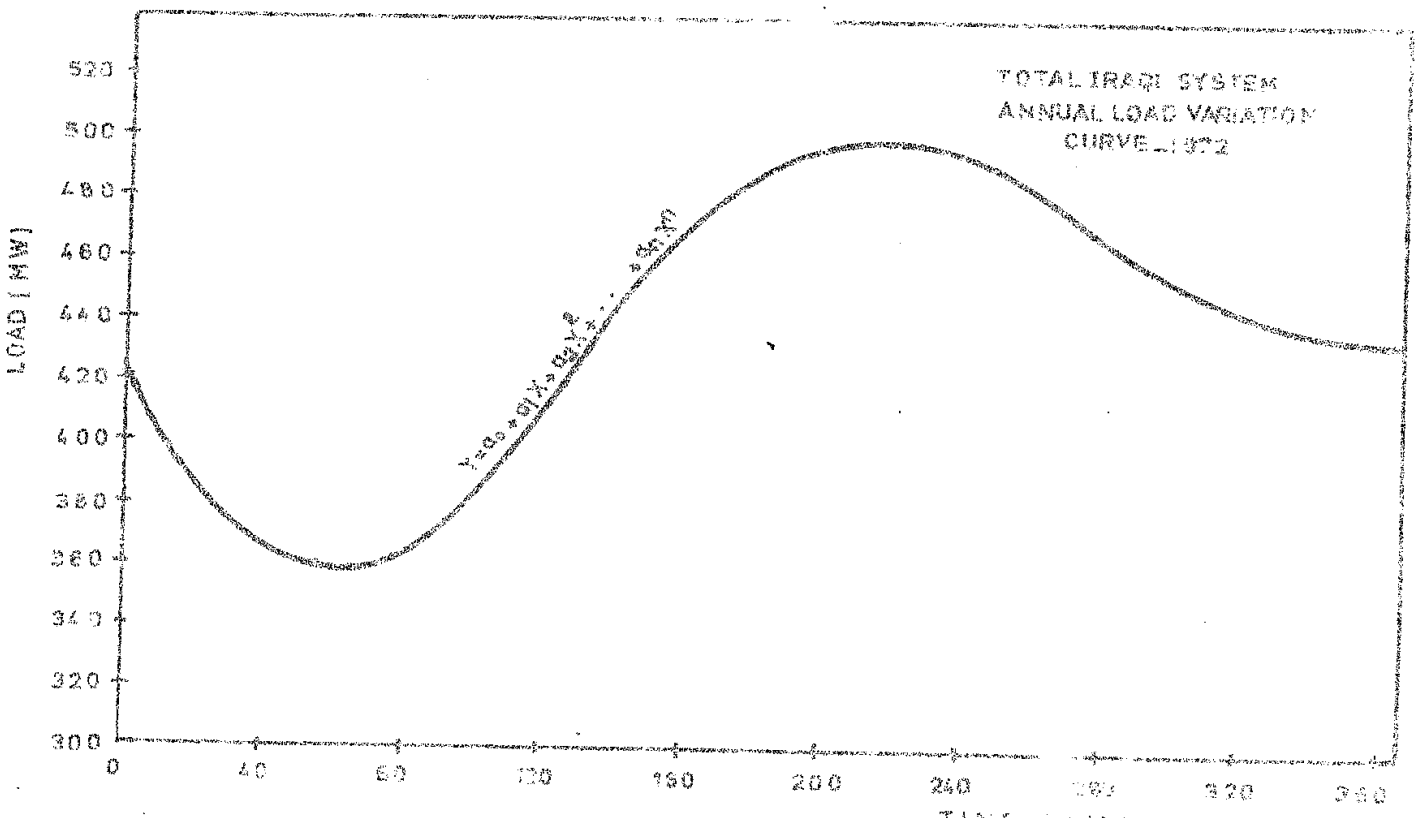
where $a_1, a_2, a_3 \ldots, a_n$ are the coefficients of the polynomial estimated by the numerical techniques.

The results of the statistical test of the load variation for the year 1972 using the least square method shows that this variation is characterised by a polynomial of the fourth order with a root mean square error of 21.517(MW). The coefficients of the polynomial are presented in table (2.1) as follows: -

Table(2.1)

POLYNOMIAL COEFFICIENTS	MAGNITUED
a_o	+ 420.909
a_1	- 2.65712
a_2	+ 0.03475
a_3	- 0.13020×10^{-2}
a_4	0.15028×10^{-6}

Fig.(2.1) shows the best curve representing the annual variation of the daily peak load for Iraqi system. It is noted that the curve is characterised by one peak and one vally. The peak occurrs in August and the vally occurrs during March.



Fig(2.1) : Best polynomial representing the annual load variation curve for Iraqi system.

2.2.2 Peak Load Duration Curves

The knowlegde of the shape of the daily peak load variation curve for a system under study is the first step of information required in determining the reliability level for that system. So, to describe the peak load variation curve for a given year, it is necessary to know the daily peak integrated load for that year. If the maximum peak load of that year is drawn as a first point and the other points are arranged in a descending order, the load duration curve for that year is obtained.

The method of least square is used in this study to obtain a general load model for the Iraqi system given in a form of polynomial equation of K-th order, togehter with the best curve fitting for the available data of the system. The study period is one year, and therefore one hundred percent on the absissa corresponds to 365 days. If the week-ends and holidays are disregarded as their contribution to the expected load loss is negligable, thus, the time span for Iraq in this case (excluding holidays) is approximately 293 days.

Table(2.2) presents the polynomial coefficients for the annual peak load duration curve as estimated by using the least square approach.

Fig.(2.2) shows the load duration curves for the total Iraqi generating system during 1972.

Fig.(2.3a) shows the load duration curve for Baghdad region.

Fig.(2.3b) also shows the load duration curves for Baghdad, the north and south regions respectively for the sake of comparison between the electrical load for these three main regions in Iraq.

Table (2.2)

Polynomial coefficients of the annual peak load duration curve for the total Iraqi system - year 1972

POLYNOMIAL COEFFICIENS	INCLUDING HOLIDAYS (WEEK DAYS)	EXCLUDING HOLIDAYS
a_0	$+ 0.511478 \times 10^{3}$	$+ 0.525376 \times 10^{3}$
a_1	$- 0.397511 \times 10^{0}$	$- 0.186904 \times 10^{1}$
a_2	$- 0.119583 \times 10^{-2}$	$+ 0.327927 \times 10^{-1}$
a_3	$+ 0.698129 \times 10^{-5}$	$- 0.304348 \times 10^{-3}$
a_4	$- 0.115048 \times 10^{-7}$	$+ 0.116233 \times 10^{-5}$
a_5	0.0000000	$- 0.156290 \times 10^{-8}$
	R.M.S of error=4.18	R.M.S of error=3.21

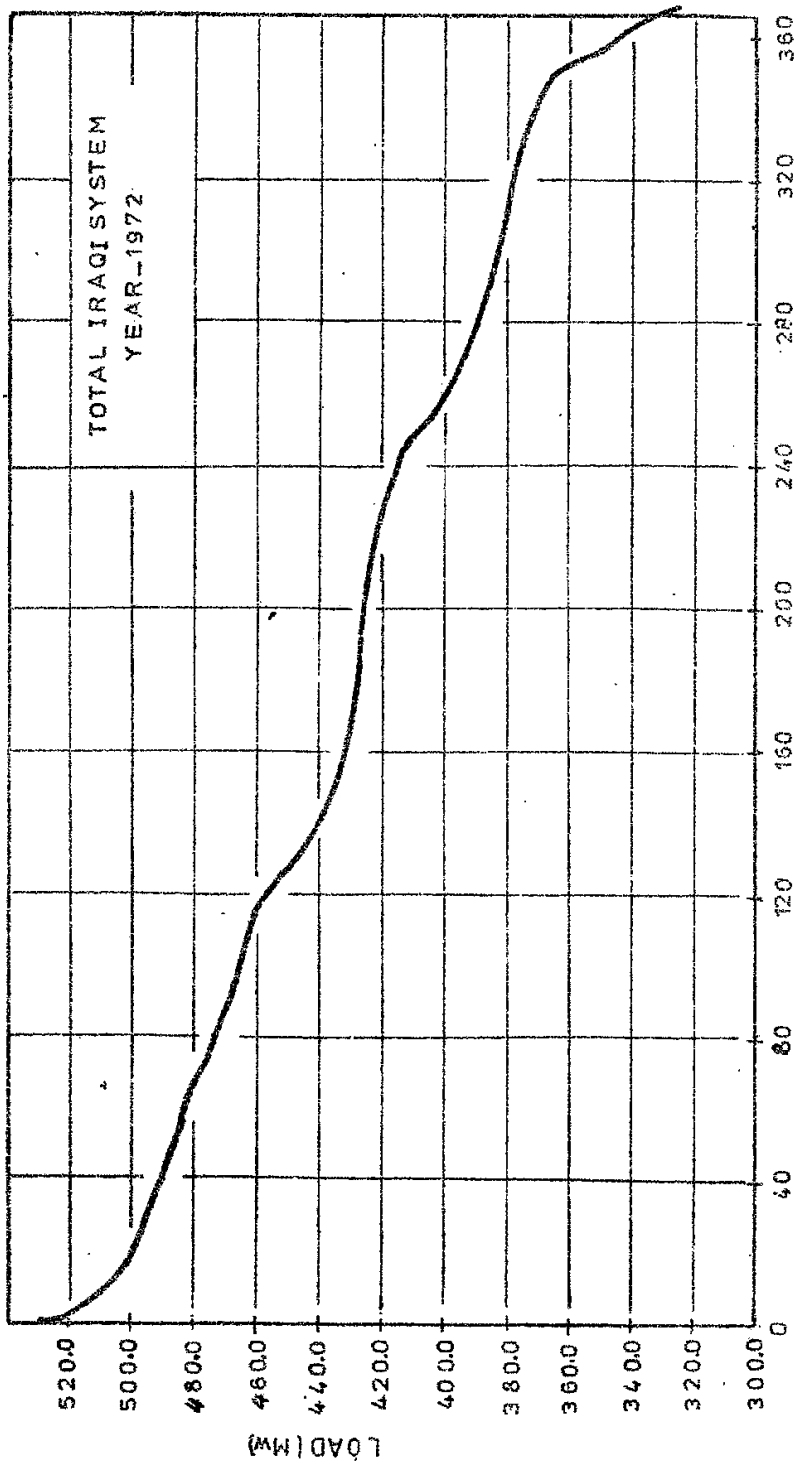
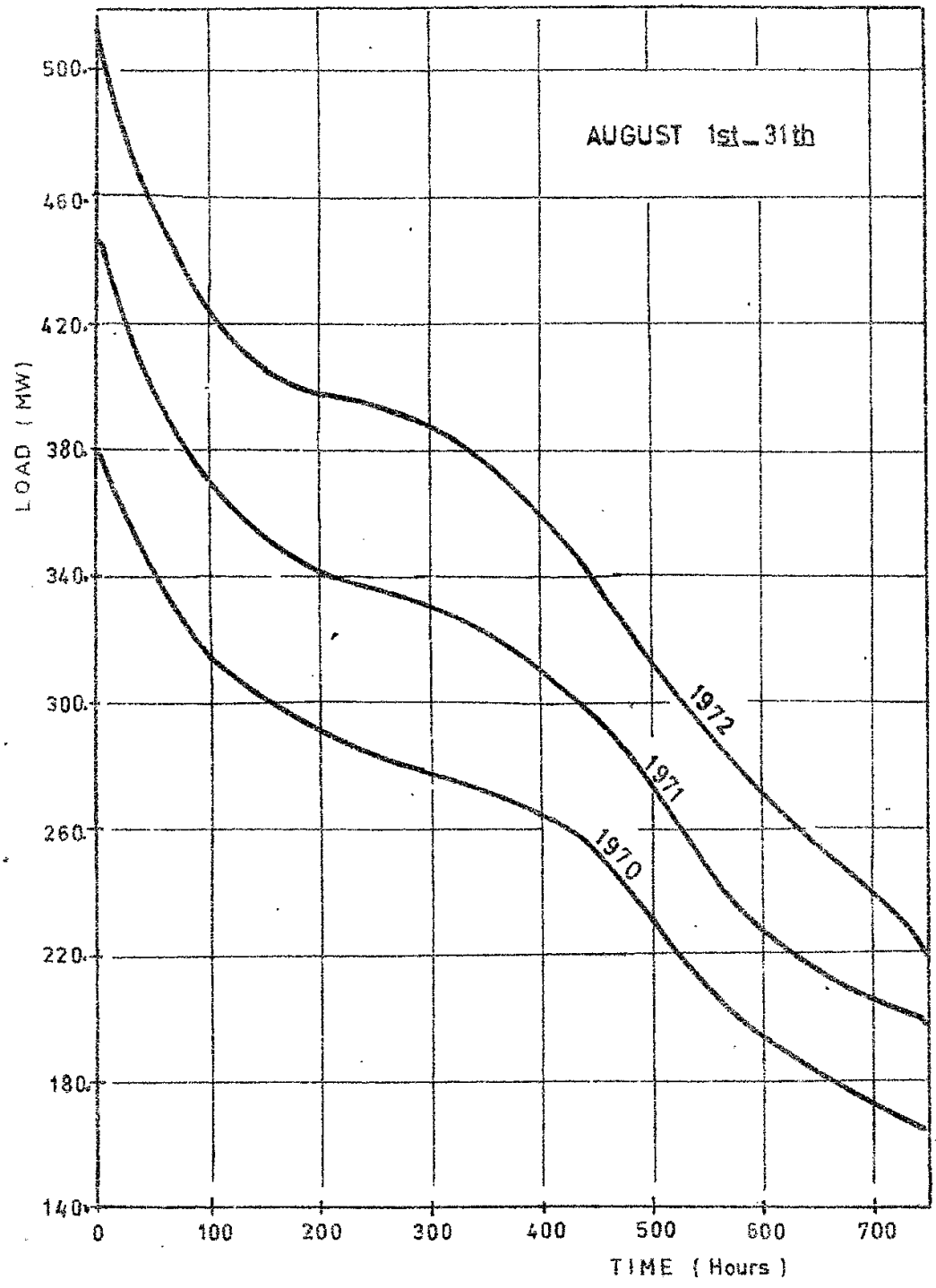
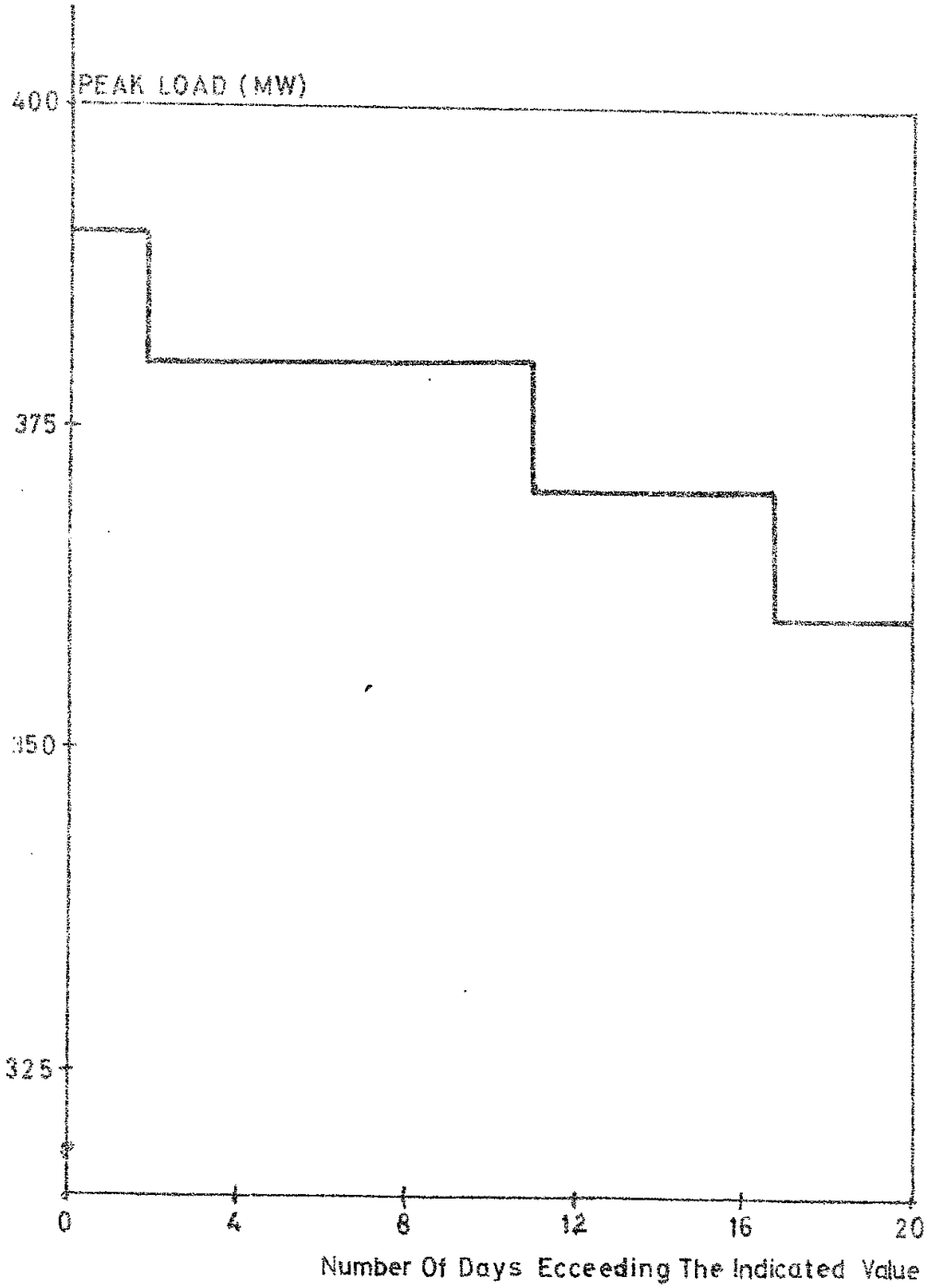


Fig.(2.2a): Annual Load Duration Curve For Iraqi System

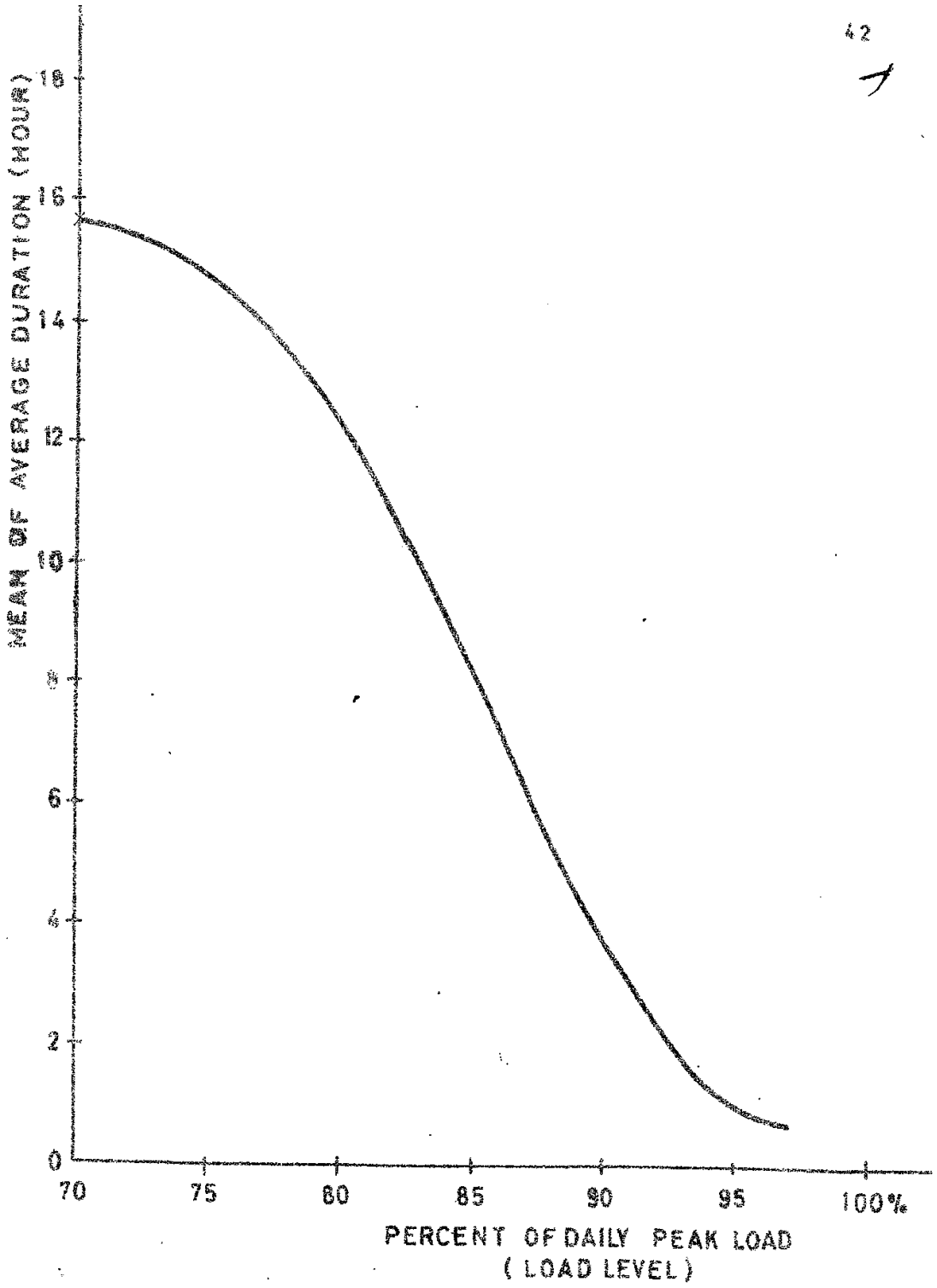


Fig(2.2b) Montly Load Duration Curve

For Total Iraqi System



Fig(2.2c) : Load Duration Curve For Iraq During 20 Days Excluding Fridays_Feb_1972



FIG(2.2d):MEAN DURATION OF THE PEAK VS LOAD LEVEL IRAQ N.E.A JAN-DEC-1972

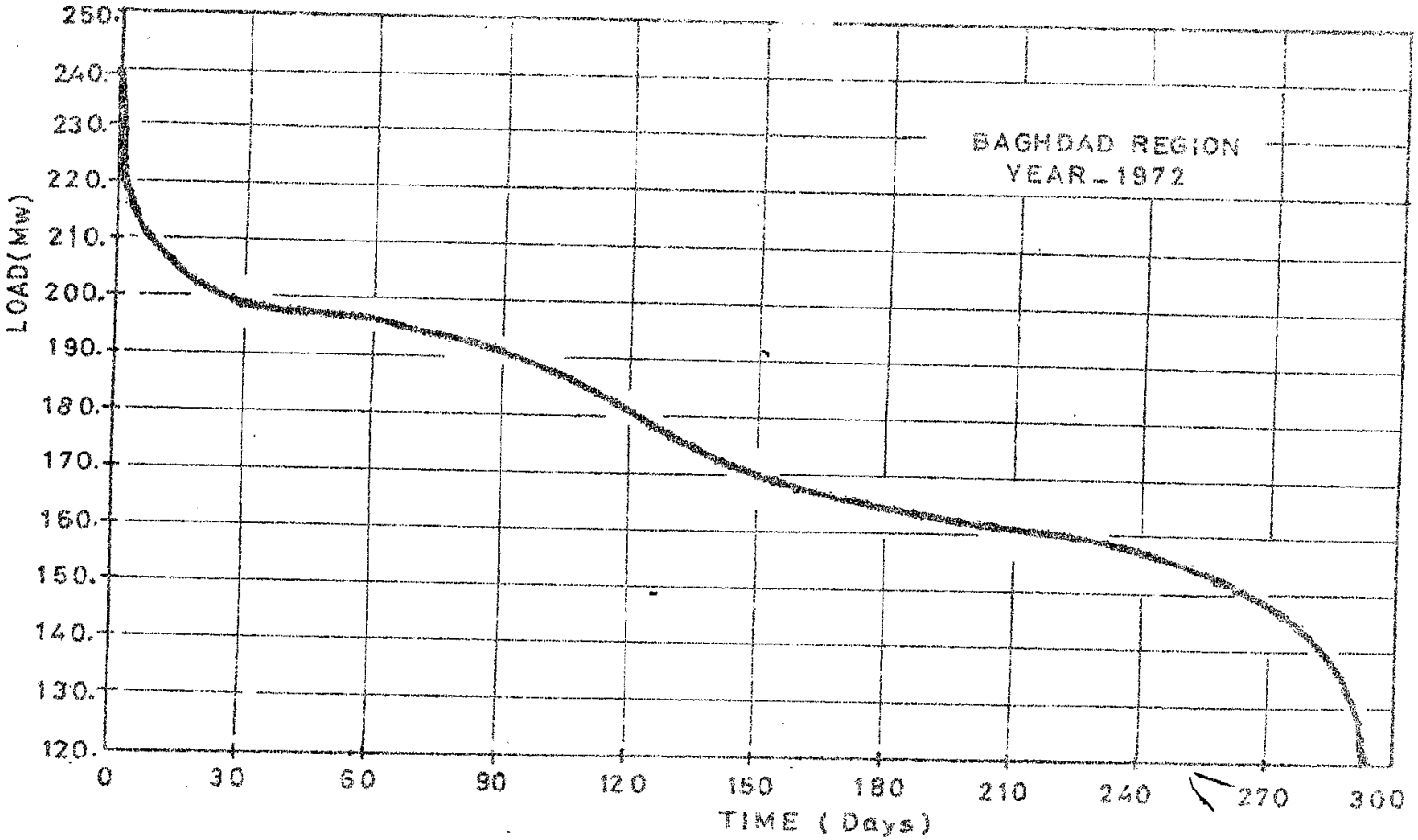


Fig (2.30) : Annual Load Duration Curve
For Baghdad Region (Excluding Holidays)

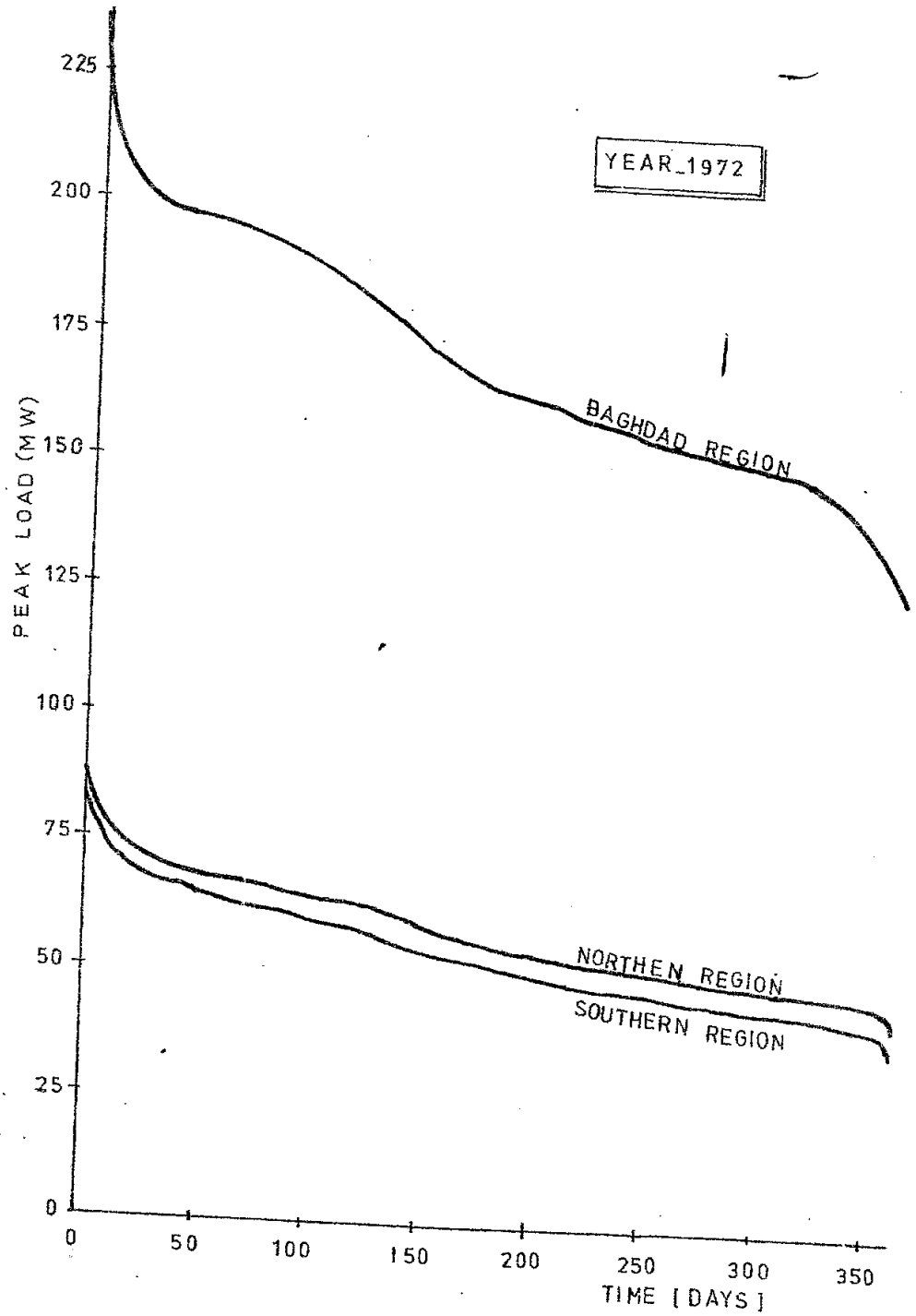


FIG.(2.3b): COMPARISON OF LOAD DURATION CURVES FOR THREE REGIONS IN IRAQ

2.2.3 Long Trend Load Forecasting

In planning unit addition where risk levels for different years are to be compared, the annual peak load forecasting for the system under study must be estimated. However, in order to obtain a general function which represents the peak load variation, the method of orthogonal polynomials (15) is suggested first because this method has a potential features as a computing technique suitable for standard programming on ordinary digital computer.

However, the basic theory and process of calculation of this method is given in more details in reference(16) But in general the peak load function can be expressed in a form of polynomial as follows: -

$$E(y) = a_0 + a_1 f_1(x) + a_2 f_2(x) + a_3 f_3(x) + \ldots + a_n f_n(x) \ldots (2.2)$$

If this polynomial is obtained, one can estimate the required terms for the period under investigation. The uncertinty in forecasting the loads by this method can be expressed in a form of the standard deviation(S.D)for each calculated value.

Data of the total Iraqi peak load for the period(1960-1972) is obtained from N.E.A, and is given in table(2.3). This data represent the load requirements and available power during the thirteen years from 1960-1972. From these

YEAR	YEARLY PEAK LOAD (MW)	YEARLY GENERATED ENERGY (MWH)
1960	107.0	369000.000
1961	137.0	565000.000
1962	168.0	713000.000
1963	174.0	785000.000
1964	205.0	934000.000
1965	232.0	1030000.000
1966	261.0	1162000.000
1967	277.0	1270000.000
1968	316.0	1491000.000
1969	366.0	1695000.000
1970	396.0	1853000.000
1971	459.0	2165000.000
1972	529.0	2512000.000

Table (2.3)

Historical Data for Load Requirements

and Available power for Iraqi System

TABLE(2.4): FOR CALCULATING THE PEAK LOAD GENERAL FUNCTION

YEAR	PEAK LOAD $\times 10^2$	F1(X)	YF1(X)	F2(X)	YF2(X)	F3(X)	YF3(X)	F4(X)	YF4(X)
1960	1.070	-6.00	-6.4	21.99	23.5	-65.99	-70.6	169.71	181.5
1961	1.370	-5.00	-6.8	10.99	15.0	0.00	0.0	-113.14	-155.0
1962	1.680	-4.00	-6.7	1.99	3.3	36.00	60.4	-164.57	-276.4
1963	1.740	-3.00	-5.2	-5.00	-8.7	48.00	83.5	-92.57	-161.0
1964	2.050	-2.00	-4.1	-10.00	-20.5	42.00	86.0	18.85	38.6
1965	2.320	-1.00	-2.3	-13.00	-30.1	24.00	55.6	109.71	254.5
1966	2.610	0.00	0.0	-14.00	-36.5	0.00	0.0	144.00	375.8
1967	2.770	1.00	2.7	-13.00	-36.0	-24.00	-66.4	109.71	303.9
1968	3.160	2.00	6.3	-10.00	-31.6	-42.00	-132.7	18.3[illegible]	59.5
1969	3.660	3.00	10.9	-5.00	-18.3	-48.00	-175.6	-[illegible].57	-838.8
1970	3.960	4.00	15.8	1.99	7.9	-36.00	-142.5	-164.57	-651.7
1971	4.590	5.00	22.9	10.99	40.4	-0.00	-0.0	-113.14	-519.3
1972	[illegible]	[illegible].00	[illegible].5	21.99	115.4	65.99	346.4	169.71	[illegible]90.9
$\sum {}^{n}F_n(x)$	34.3		58.7		34.0		44.2		2.7
$\sum F_n(x))^2$		181.[illegible]		2001.[illegible]		20591.9		*******	

TABLE (2.4 Cont.): RESULTS OF CALCULATION OF THE ORTH.POLYNOMIAL

YEAR	YSQUARE
1960	1.144900
1961	1.876899
1962	2.822399
1963	3.027599
1964	4.202499
1965	5.382398
1966	6.812098
1967	7.672900
1968	9.985599
1969	13.39559
1970	15.68159
1971	21.06804
1972	27.56250

SUM.OF Y SEQ. = 120.635

ADDITIONAL INFORMATIONS

THE AVERAGE OF X = 7.00

THE AVERAGE OF Y = 2.7

VARIANCE(1) =11.652

VARIANCE(2) =11.0467

VARIANCE(3) =10.6554

VARIANCE(4) =10.3277

RESIDUAL =43.6825.

THE POLYYNOMIAL COEFFICIANTS ARE

$A_0 = 2.78692$ $A_1 = 0.322692$

$A_2 = 0.7078 \times 10^{-1}$ $A_3 = 0.2147 \times 10^{-2}$

$A_4 = 0.135956 \times 10^{-4}$.

THE MINIMUM STANDARD DEVIATION IS =0.056562. WITH THE FOLLOWING COEFFICIENTS :

2.78692	0.3226	0.017018
0.2147×10^{-2}	0.135956×10^{-4}	

information the polynomial of the functions fr(x) given in eq.(2.2) are found according to this method by using the IBM 1130 digital computer, and the results are shown in table (2.4).

The coefficients $a_0, a_1, a_2, \ldots, a_n$ eq.(2.2) are evaluated from table (2.4) and the result is given in table(2.5).

Table (2.5)

ORTHOGONAL POLYNOMIAL COEFFICIENTS

POLYNOMIAL COEFFICIENTS	MAGNITUED x 10^2
a_0	2.786920
a_1	0.322692
a_2	0.170178×10^{-1}
a_3	0.214730×10^{-2}
a_4	0.135956×10^{-4}

Again from table (2.4) and the above calculated values of the coefficients a_o to a_4, the general function of the peak load may then be written in the following form:

$$E(y)=278.692+32.2692\, f_1(x)+1.70178\, f_2(x)+0.21473\, f_3(x) + 0.00135956\, f_4(x) \text{ (MW)} \qquad \ldots\ldots(2.3)$$

From this simplified trend function, the peak load natural growth for the Iraqi system for future years may

be easily estimated, thus giving E(y) in M.W. The peak load forecasts for the period (1972-1985) is given in table(2.6).

It must be noted that the large industrial, agricultural loads and newly developed plans are excluded from the prediction. If such loads are taken into account they may largely affect the trend of the natural growth and they should be added to the available figures obtained from the orthogonal polynomials.

Fig.(2.4) shows the peak load forecast for the period 1972-1985.

2.3 Digital Computer In timing Units Addition

2.3.1 The outage capacity probability computations

It has been shown in chapter one that the binomial expansion is one of the fundamental probability function that is applied to the equipement outage problem. This type of expansion is used in this thesis to construct the outage capacity probability table (OCPT) which is considered as a first step for system reliability evaluation. The computational efforts of this expansion are stored in the core of the computer as a subroutine with a flow chart as shown in fig. (2.5).

Table (2.6) Estimation of Total peak Load of Iraqi system for the period (1973 - 1985)

YEAR	USING ORTHOGONAL POLYNOMIAL METHOD (MW)	USING STRAIGHT LINE METHOD - SLOPE = 10 % (MW)
1973	577.0	577.5
1974	626.0	635.24
1975	~~690.0~~	~~698.76~~
1976	760.0	763.65
1977	830.0	845.50
1978	910.0	930.0
1979	998.0	1025.0
1980	1065.0	1125.5
1981	1180.0	1237.92
1982	1300.0	1361.20
1983	1420.0	1497.0
1984	1590.0	1647.6
1985	1755.0	1812.0

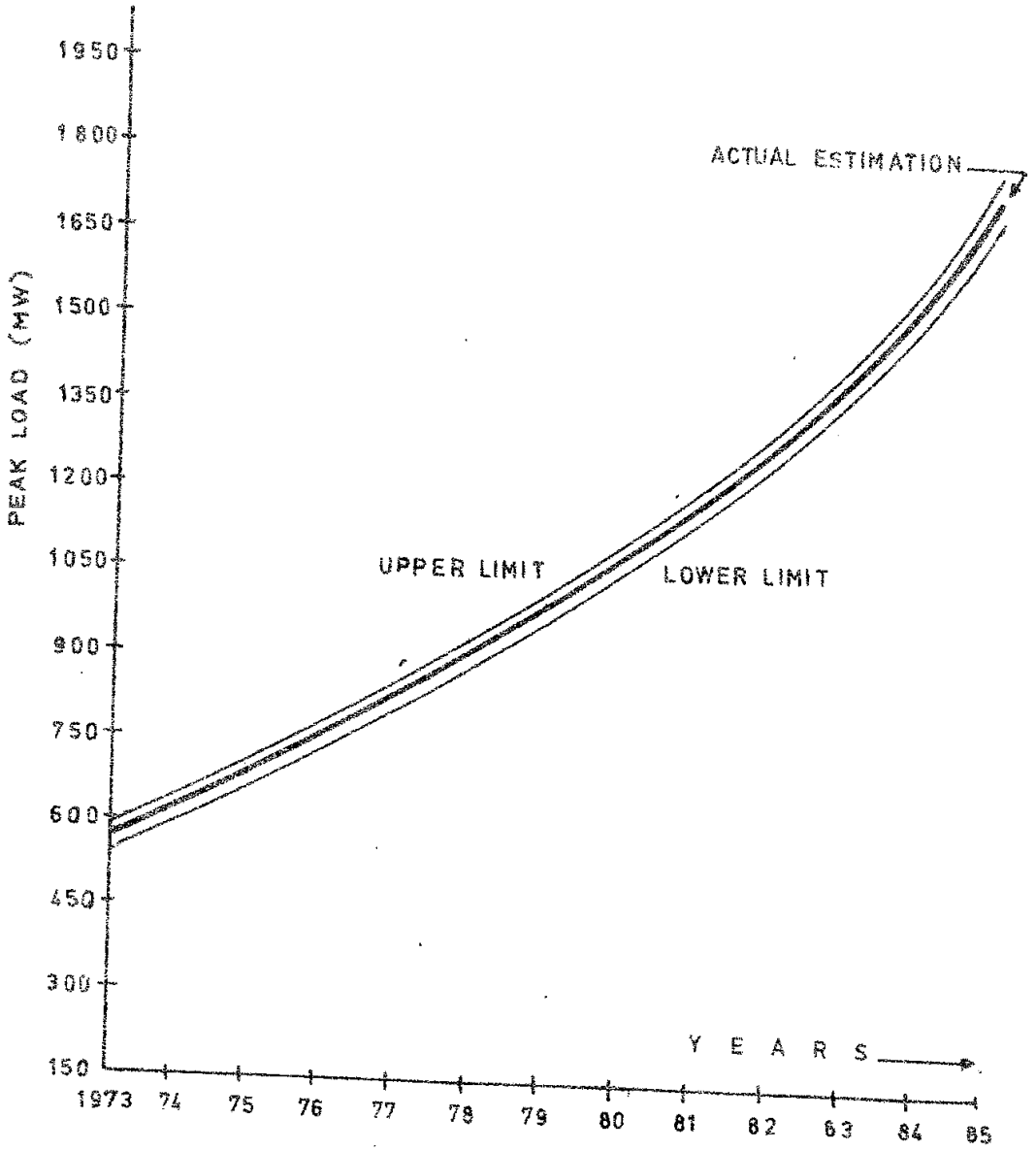


FIG.[2.4] : LONG TREND LOAD FORECAST FOR IRAQI SYSTEM USING ORTHOGONAL POLYNOMIAL METHOD

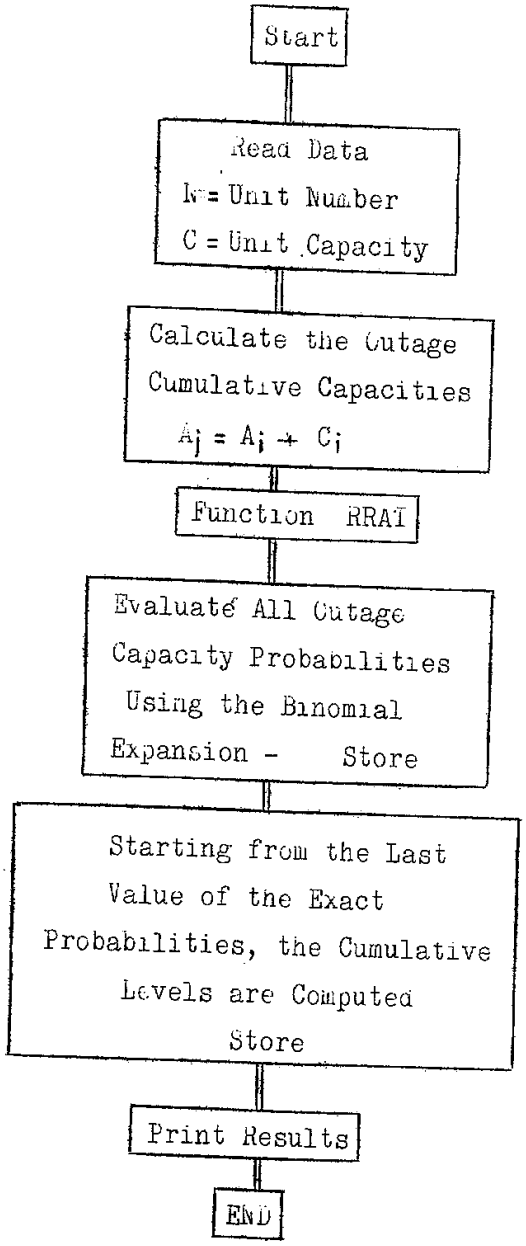

Start
Read Data
N = Unit Number
C = Unit Capacity
Calculate the Outage Cumulative Capacities
$A_j = A_i + C_i$
Function RRAT
Evaluate All Outage Capacity Probabilities Using the Binomial Expansion - Store
Starting from the Last Value of the Exact Probabilities, the Cumulative Levels are Computed Store
Print Results
END

Fig.(2.5): - The computer flow chart for subroutine (SO C P T)

Table 2.7

OUTAGE CAPACITY PROBABILITY TABLE FOR THE 22 UNIT SYST.

UNIT OUT	CAPACITY OUT	EXACT PROB	CUM PROB
0	0.00000	0.6411693E 00	0.9999978E 00
1	25.00000	0.2878720E 00	0.3588286E 00
2	50.00000	0.6168692E-01	0.7095669E-01
3	75.00001	0.8392784E-02	0.9269768E-02
4	100.00001	0.8135868E-03	0.1769844E-03
5	125.00001	0.5977377E-04	0.6339767E-04
6	150.00003	0.3456308E-05	0.3623906E-05
7	175.00003	0.1612273E-06	0.1675979E-06
8	200.00003	0.6169418E-08	0.6370586E-08
9	225.00003	0.1958546E-09	0.2011686E-09
10	250.00003	0.5196149E-11	0.5314031E-11
11	275.00006	0.1156842E-12	0.1178828E-12
12	300.00006	0.2164163E-14	0.2198588E-14
13	325.00006	0.3397433E-16	0.3442496E-16
14	350.00006	0.4457279E-18	0.4506229E-18
15	375.00006	0.4851463E-20	0.4899095E-20
16	400.00006	0.4331667E-22	0.4363045E-22
17	425.00006	0.3120051E-24	0.3137814E-24
18	450.00006	0.1768738E-26	0.1776560E-26
19	475.00006	0.7599310E-29	0.7622618E-29
20	500.00006	0.2326321E-31	0.2330847E-31
21	525.00012	0.4521522E-34	0.4525716E-34
22	550.00012	0.4194366E-37	0.4194366E-37

$E = 10^{X}$

Table (2.7) gives the results of the application of this subroutine for a system containing twenty two similar units. The name given for this subroutine is OCPT.

2.3.2 Unit Addition Computing Technique

A new technique is developed in this thesis for computing the new resultant outage capacity probability table after an addition of a new unit to the old system using digital computer.

Now, assume that for a given system of (N) similar units the outage capacity probability table is constructed first prior to the addition of a new unit as shown in the following table (2.8).

Table 2.8

CAPACITY OUTAGE	EXACT PROBABILITY	CUMULATIVE PROBABILITY
C_0	A_0	$P_0 = \sum_{i=C}^{N} A_i$
C_1	A_1	.
C_2	A_2	.
.	.	$P_{N-1} = A_N + A_{N-1}$
C_N	A_N	$P_N = A_N$
.	.	

Where C_i indicates the Capacity outage being Considered, and P_i gives the cumulative probability of an outage equal to or greater than C_i.

Now, if a new unit with capacity B_1 and outage rate q_1 is added; then this unit can be represented by the following indices:

B_1 = Capacity of the added unit in (MW)

B_0 = Outage capacity or unit curtailment = 0(MW)

q_1 = Unavailability of the unit.

q_0 = Exact availability of the incoming unit = $1-q_1$.

These representation of the existing and the incoming additional unit will now be multiplied together.

The column vector representing the capacity outage levels is given by adding B_1 and B_0 to the given capacity outage column (C) & ($\bar{C}$) as follows:-

$$[B_0] + [C_i] = [C] \qquad \ldots\ldots(2.4)$$

$$[B_1] + [C_i] = [\bar{C}] \qquad \ldots\ldots(2.5)$$

The total resulting column [K] is equal to the summation of the above two columns with the results arranged in an ascending order; therefore :

$$K_1 \leq K_2 \leq K_3 \ldots\ldots \leq K_n$$

(n) is the resultant number of capacity level in column [K] .

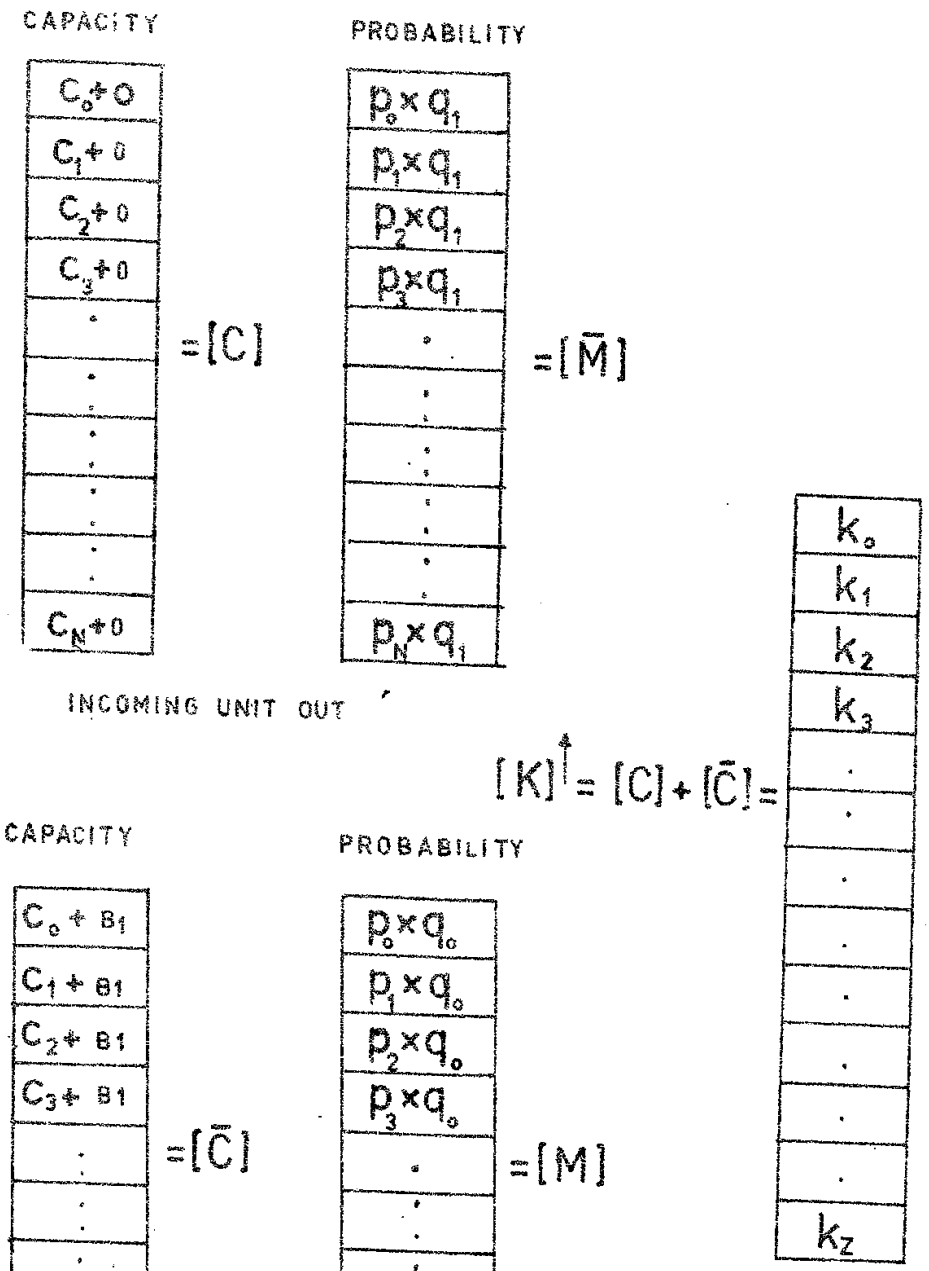


FIG.[2.6a] : OBTAINIG THE OUTAGE C.P.T. AFTER AN ADDITION OF A NEW UNIT

In order to obtain the consolidated column for the cumulative probability, $[M]$ & $[\bar{M}]$ therefore

$$[P_i] \times [q_0] = [M] \qquad \ldots\ldots(2.6)$$

$$[P_i] \times [q_1] = [\bar{M}] \qquad \ldots\ldots(2.7)$$

Summing all identical states and arranging these values with their relative outage capacities, the resultant Consolidated probability column is given by $[\bar{P}]$.

This technique has been inplemented in a segment of computer program in a form of a stored subroutine . The flow chart of this subroutine is shown in fig.(2.6 b)

The name given for this subroutine is (ROLSE).

The application of this subroutine is used for a given system containing 5-50 MW units for total installed capacity of 250 MW. This is done in order to see how the addition of more generating units affects the expected load loss probability.

It is assumed that additional units each of 50 MW with forced outage rate of 0.02, the change in risk level is given in the following table :

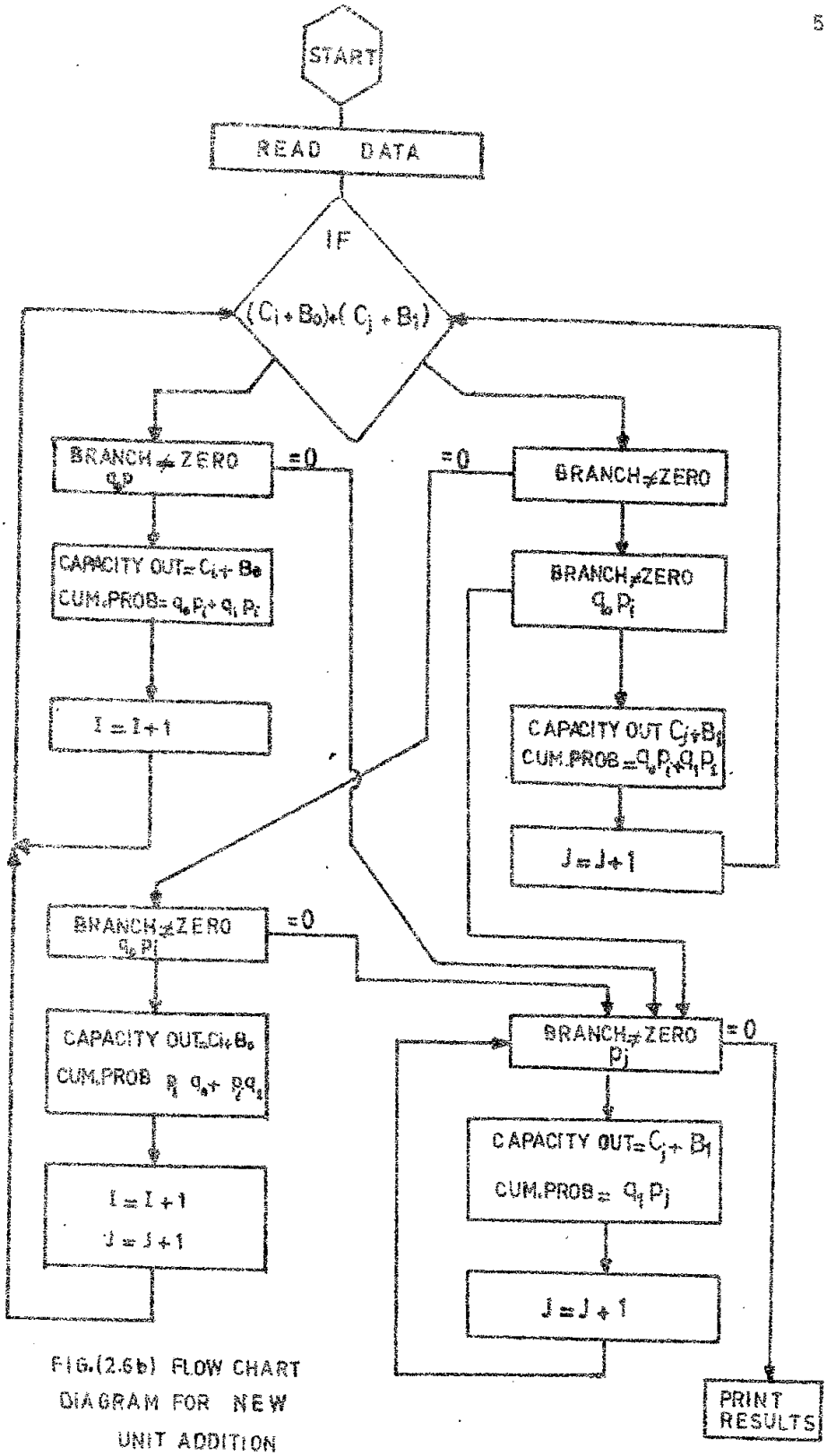


FIG.(2.6b) FLOW CHART DIAGRAM FOR NEW UNIT ADDITION

50 MW unit Addition Scheme

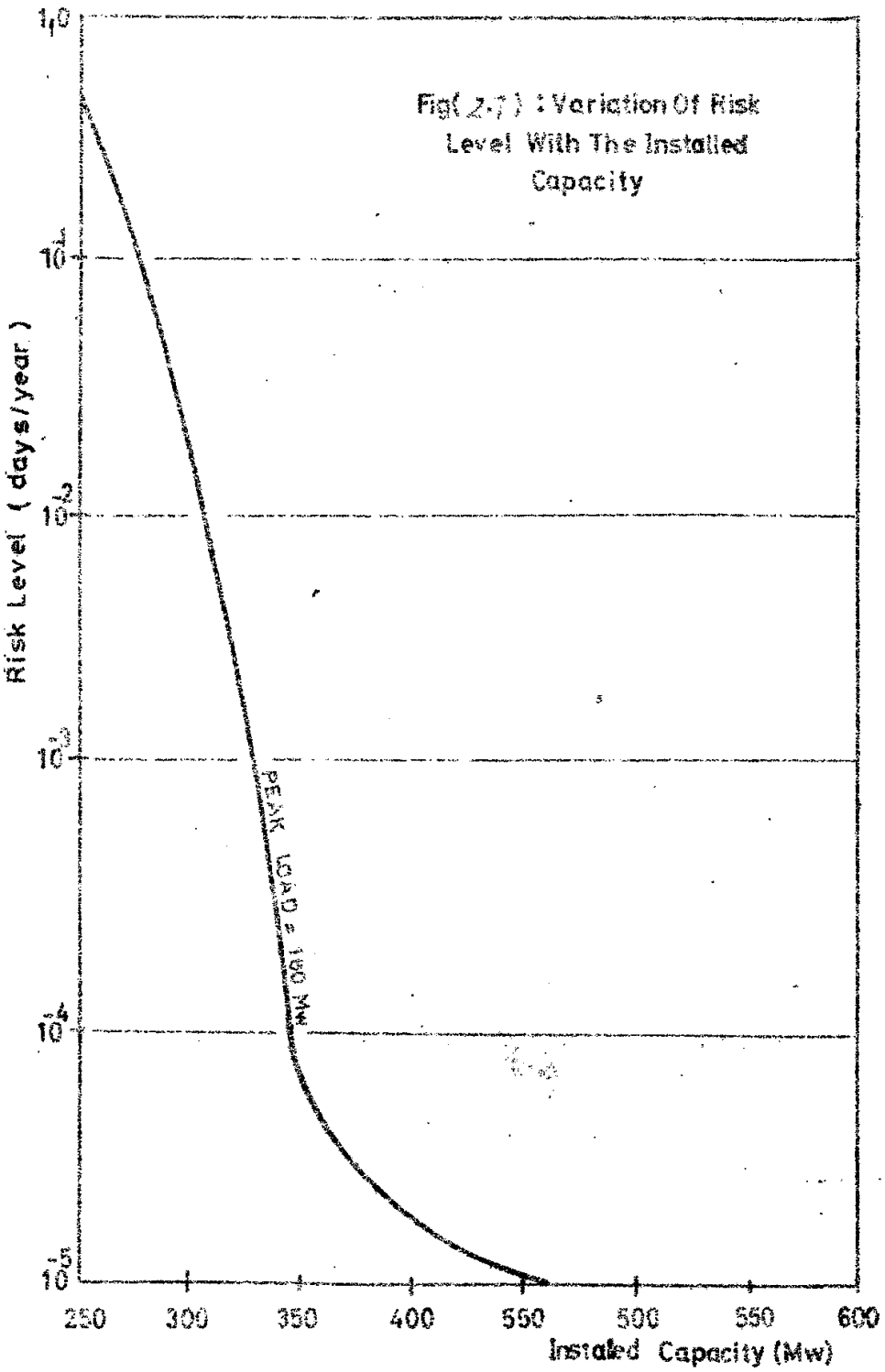
Unit Addition	System Capacity in (MW)	Expected load loss Days/year
0	250.0	0.5962880
1	300.0	0.0236120
2	350.0	0.00082141
3	400.0	0.00002617
4	450.0	0.7830833×10^{-6}
5	500.0	0.223250×10^{-7}
6	550.0	0.6128988×10^{-9}
7	600.0	$0.1632000 \times 10^{-10}$
8	650.0	0.423890×10^{-12}

Table (2.9) showing the Variation of risk level with the variation of system installed capacity

These results are drawn on a log/linear paper and shown in Fig(2.7). It is noticed that addition of one unit lower the probability of loss of load from approximatly 0.6 day per one year to something like 1 day per 50 years.

2.7 Use of " calabrese " Technique to Determine the Static reserve position for the Iraqi Generating System

The " calabrese " or loss of load probability technique is used to make an estimate for risk levels and expansion



Fig(2.7) : Variation Of Risk Level With The Installed Capacity

scheme for Iraqi generating system reserve for the period 1972-1990.

A computer program is developed for using this technique to perform this study, the flow chart of this program is shown in figure (2.8)

The peak load is assumed to increase by ten percent every year with the basic load model remaining unchanged. One load model is assumed to hold throughout and no maintenance is included in the study.

The variation in reliability measures results only from change in the peak load and from unit addition.

2.7.1 The Generating system model

The knowledge of the type of the system generating facilities and the shape of the daily peak load curve for a given system, is the first pieces of information required so that the loss of load probability method can be applied.

Table (2.10) gives astatistical data about the total Iraqi generating system for the year of study. The type and the number of machines in the system is included together with the total demand for different regions.

In order to develop a model for Iraqi generating system which include a large number of generating units of different capacities, and to minimize the serveral possible

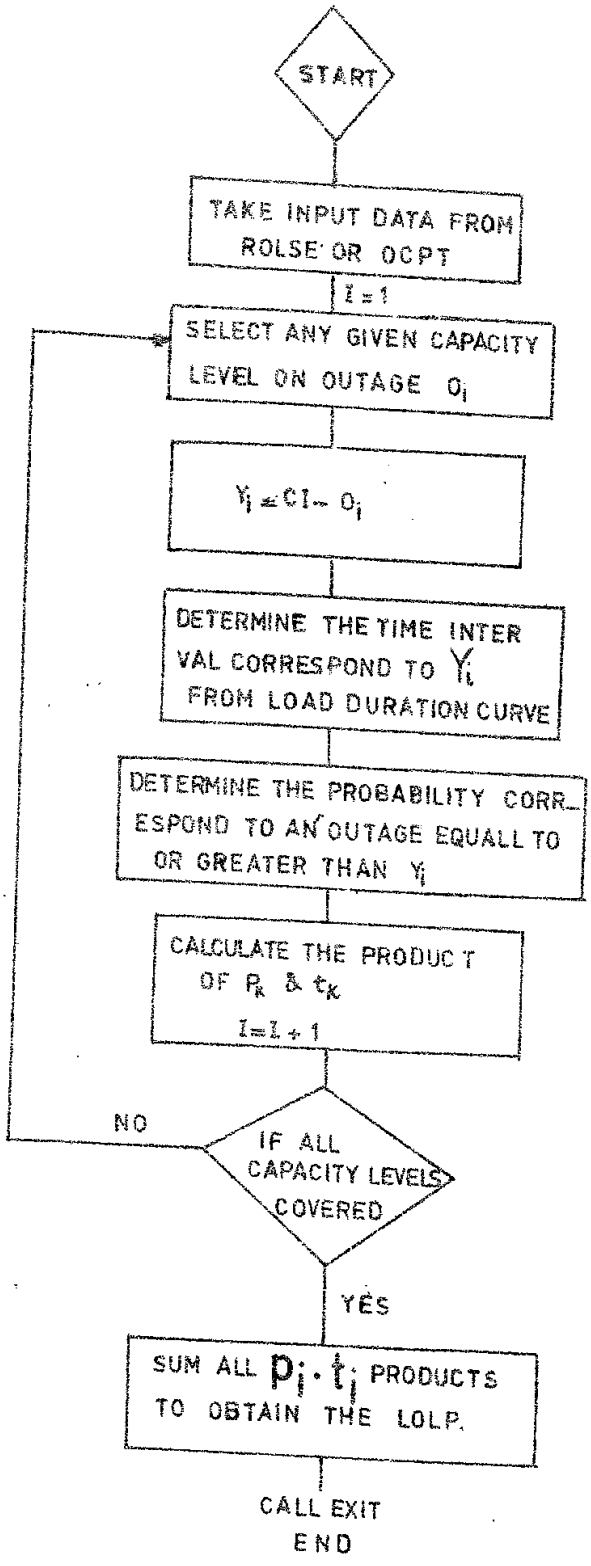

START
TAKE INPUT DATA FROM ROLSE OR OCPT
I = 1
SELECT ANY GIVEN CAPACITY LEVEL ON OUTAGE O_i
$Y_i = CI - O_i$
DETERMINE THE TIME INTER VAL CORRESPOND TO Y_i FROM LOAD DURATION CURVE
DETERMINE THE PROBABILITY CORR_ ESPOND TO AN OUTAGE EQUALL TO OR GREATER THAN Y_i
CALCULATE THE PRODUCT OF P_k & t_k
I = I + 1
NO
IF ALL CAPACITY LEVELS COVERED
YES
SUM ALL $p_i \cdot t_i$ PRODUCTS TO OBTAIN THE LOLP.
CALL EXIT
END

FIG.(2.8): FLOW CHART OF CALABRESE TECHNIQUE

Table 2.6 Statistical Data for 1972 Year of Study

System	Total. Capacity MW	Max or peak Load MW	Capab. of plants MW	No.of Plants	No.Thermal Units Turbine	Boilers	Hydro Units	Largest unit in service
BER	362.0	220.0	362.0	3	-	-	0	67.5
CIS	180.0	118.0	180	2	-	-	0	25.0
NIRS	60.0	77.0	60.0	1	-	-	0	15.0
SERS	45.0	90.0	45.0	1	-	-	0	15.0
System Total	647.0	525.0	647.0	7			0	

BER : - Baghdad Electricity Region

CIS : - Central Iraq System excluding Baghdad Region.

NIRS: - North Iraq Region.

SERS:-- South Iraq Electricity Region.

discrete capacity outage levels, a reasonable average value of capacity for the existing units has been estimated.

This average value reduce the number of the actual unit in the system by grouping these units into identical capacity groups prior to building the table of capacity outage levels or (the (GSM)).

The inaccuracies introduced from this averaging and approximation, when computing the risk level, can be neglected. Also the flexibility of the resulting model due to removing a units for periodic inspection and maintenance is also neglected, and the outage table is only for the available units which are in service.

Table (2.11) gives the GSM for the system. The average unit size of 25 MW, the small size units at sarrafiya power station are grouped and rounded to a bigger unit sizes.

The calculation to show the probability of capacity availability or outage is relatively tedious; however, it is voluminous and therefore is not reproduced here. These computations are programed on the digital computer to perform the study.

Now the Iraqi generating system is considered as a uniform system; that is; all units are equall in size, outage

TABLE (2.4). ESTIMATED GENERATING SYSTEM MODEL FOR IRAQ

CAPACITY ON OUTAGE(MW)	EXACT PROBABILITY	CUMULATIVE PROBABILITY	INDIVIDUAL FREQUENCY	MEAN TIME TO FAILURE
0.0	0.6411693E 00	0.9999978E 00	0.2821142E 00	0.3544663E 01
25.0	0.2878720E 00	0.3588286E 00	0.2648421E 00	0.3775835E 01
50.0	0.6168692E-01	0.7095669E-01	0.8636167E-01	0.1157921E 02
75.0	0.8392784E-02	0.9269768E-02	0.1577842E-01	0.6337767E 02
100.0	0.8135868E-03	0.8769844E-03	0.1920064E-02	0.5208159E 03
125.0	0.5977377E-04	0.6339767E-04	0.1697574E-03	0.5890757E 04
150.	0.3456308E-05	0.3623906E-05	0.1147494E-04	0.8714642E 05
175.0	0.1612273E-06	0.1675979E-06	0.6126639E-06	0.1632216E 07
200.0	0.6169418E-08	0.6370586E-08	0.2640510E-07	0.3787147E 08
225.0	0.1958546E-09	0.2011686E-09	0.9322680E-09	0.1072653E 10
250.0	0.5196149E-11	0.5314031E-11	0.2722781E-10	0.3672715E 11
275.0	0.1156842E-12	0.1178828E-12	0.6617140E-12	0.1511227E 13
300.0	0.2164163E-14	0.2198588E-14	0.1341781E-13	0.7452781E 14
325.0	0.3397433E-16	0.3442496E-16	0.2269485E-15	0.4406286E 16
350.0	0.4457279E-18	0.4506229E-18	0.3191411E-17	0.3133410E 18
375.0	0.4851463E-20	0.4895093E-20	0.3706518E-19	0.2697950E 20
400.0	0.4331667E-22	0.4369045E-22	0.3517313E-21	0.2843079E 22
425.0	0.3120051E-24	0.3137814E-24	0.2683244E-23	0.3726833E 24
450.0	0.1760738E-26	0.1776360E-26	0.1606014E-25	0.6226597E 26
475.0	0.7593810E-29	0.7622610E-29	0.7264939E-28	0.1376474E 29
500.0	0.2326321E-31	0.2330947E-31	0.2333926E-30	0.4281506E 31
525.0	0.4511522E-34	0.4525716E-34	0.4736641E-33	0.2102324E 34
550.0	0.4194366E-37	0.4194366E-37	0.4613802E-36	0.2167409E 37

X

E=X=10

rate; and average duration of outage, then the Calabrese technique can be applied to study the reserve generating capability of the system with the following assumptions:

1. The reliability degrees for use in determining required generating capacity addition is constant.
2. Unit size variation is used as a base of comparison of various risk levels.

Based on the above assumptions together with the obtained data for the system load characteristics, an expansion studying scheme for Iraqi system is made in the following subsections.

2.7.2 An Expansion of Studying Scheme For Iraqi System Reserve

The informations required for studying the Iraqi system reserve for 1972-90 using the constant risk criterion are given in a form of computer cards. The computer start to evaluate the risk level for the given system; if this is higher than a given value, a new unit will be added to improve the risk level of the system.

The timing of unit addition is done by a special computer program in a form of subroutine developed in this thesis.

The study starts with addition of 50 MW unit capacity to the system. Table (2.12) gives the result for each subsequent addition of this unit starting from 1972.

It is seen from the table that this size is not sufficient to improve the risk level during one year; i.e; for 1975 it is necessary to add two units each of 50MW capacity such that the risk level will be improved, the same problem arizes for the years 1977-80, where the program start looping in 1979 and no improving results are obtained.

Hence the 50 MW unit size is not proper at all for Iraqi future expansion.

2.7.2.1 100 MW Unit Addition Scheme

The results obtained from 100 MW unit additions up to 1990 are given in table (2.13) . It is seen that this unit size improved the risk level by yearly addition of this unit up till 1980. The risk level is not improved over this year unless more than one unit addition is performed.

Hence the 100 MW unit size is suitable for the Iraqi system expansion schemes up to 1980, and would have to be added in the years 72,73,75,76,78,79 and 80.

TABLE (2.12)

50 MW UNIT ADDITION SCHEME

YEAR OF STUDY	PEAK LOAD(MW)	TOTAL CAPACITY(MW)	RISK LEVEL DAYS/YEAR	WETHER UNIT ADD.REQUIRED
1972	525.0	550.0	5.615	YES
CAPACITY OF UNIT ADDED = 50 MW		OUTAGE RATE (O.R) = 0.02		AVA= 0.98
1972	525.0	600.0	0.33725	NO
1973	577.0	600.0	25.46	YES
CAPACITY OF UNIT ADDED = 50 MW			(O.R) = 0.02	AVA = 0.98
1973	577.0	650.0	0.413653	NO
1974	635.24	650.0	11.993	YES
CAPACITY OF UNIT ADDED = 50 MW			(O.R) = 0.02	AVA = 0.98
1974	635.24	700.0	0.954	NO
1975	698.77	700.0	19.59	YES
CAPACITY OF UNIT ADDED = 2x50 MW			(O.R) = 0.92	AVA = 0.98
1975	698.77	800.0	0.171	NO
1976	768.65	800.0	6.91	YES
CAPACITY OF UNITS ADDED = 50 MW			(O.R) = 0.02	AVA = 0.98
1976	768.65	850.0	0.823	NO
1977	845.51	850.0	19.80	YES
CAPACITY OF UNITS ADDED = 2 x 50 MW			(O.R) = 0.02	AVA = 0.98
1977	845.51	950.0	0.370	NO
1978	930.06	950.0	13.16	YES
CAPACITY OF UNITS ADDED = 2x50 MW			(O.R) = 0.02	AVA = 0.98
1978	930.06	1050.0	0.87	NO
1979	1023.07	1050.0	22.32	YES

The programme start looping and no results obtained.

TABLE (2.13)

100 MW UNIT ADDITION/SCHEME

YEAR OF STUDY	PEAK LOAD(MW)	TOTAL CAPACITY(MW)	RISK LEVEL DAYS YEAR	WETHER UNIT ADDITION REQUIRED
1972	525	550.0	3.613	YES
CAPACITY OF UNIT ADDED = 100 MW			OUTAGE RATE = 0.02	AVAILABILITY=0.98
1972	525	650.0	0.3946875	NO
1973	577.5	650.0	2.7420	YES
CAPACITY OF UNIT ADDED = 100.00 MW		OUTAGE RATE	= 0.02	AVAILABILITY= 0.98
1974	577.5	750.0	0.06859	NO
1974	635.24	750.0	1.31216	NO
1975	698.77	750.0	0.7059642	YES
CAPACITY OF UNIT ADDED = 100.0 MW		UNITED RATE = 0.02		AVAILABILITY=0.98
1975	698.77	850.0	0.9909816	NO
1976	768.65	850.0	7.3464	YES
CAPACITY OF UNIT ADDED =100.00 MW		OUTAGE RATE = 0.02		AVAILABILITY=0.98
1976	768.65	950.0	0.3974023	NO
1977	845.51	950.0	0.5295165	NO
1978	930.06	950.0	7.13258	YES
CAPACITY OF UNIT ADDED= 100.00 MW		OUTAGE RATE= 0.02		AVAILABILITY=0.98
1978	930.06	1050.0	0.95601	NO
1979	1023.07	1050.0	0.1083498	YES
CAPACITY OF UNIT ADDED = 100.00 MW		OUTAGE RATE = 0.02		AVAILABILITY=0.98
1979	1023.07	1150.0	0.34263	NO
1980	1125.38	1150.0	11.6993	YES
CAPACITY OF UNIT ADDED = 100.0 MW		OUTAGE RATE = 0.02		AVAILABILITY =0.98
1980	1125.38	1250.0	2.366422	YES

CAPACITY OF UNIT ADDED = 100.0 MW		OUTAGE RATE = 0.02		AVAILABILITY 0.98
1980	1125.38	1350.0	0.4523	NO
1981	1237.92	1350.0	7.269755	YES
			O.R = 0.02	AVAIL. = 0.98
CAPACITY OF UNIT ADDED = 100.MW				NO
1981	1237.92	1450.0	1.113213	YES
1982	1361.71	1450.0	16.93745	AVAIL. = 0.98
			O.R = 0.02	NO
CAPACITY OF UNIT ADDED = 100.0 MW				YES
1982	1361.71	1550.0	0.4723	AVAIL. = 0.98
1983	1997.88	1550.0	9.560796	NO
			O.R = 0.02	YES
CAPACITY OF UNIT ADDED = 100.0 MW				AVAIL. = 0.98
1983	1497.88	1650.0	1.7793	YES
			O.R = 0.02	AVAIL = 0.98
CAPACITY OF UNIT ADDED = 100.0 MW				NO
1983	1497.88	1750.0	0.259320	YES
1984	1647.67	1750.0	10.200	AVAIL = 0.98
			O.R = 0.02	NO
CAPACITY OF UNIT ADDED = 100.0 MW				YES
1984	1647.60	1850.0	0.4503	AVAIL. = 0.98
1985	1812.43	1850.0	10.1450	NO
			O.R = 0.02	YES
CAPACITY OF UNIT ADDED = 100.0 MW				AVAIL. = 0.98
1985	1812.43	1950.0	3.352255	YES
			O.R = 0.02	AVAIL. = 0.98
CAPACITY OF UNIT ADDED = 100.0 MW				NO
1985	1812.43	2050.0	0.890525	YES
1986	1993.0	2050.0	11.10654	AVAIL. = 0.98
CAPACITY OF UNIT ADDED = 100.0 MW			O.R = 0.02	

1986	1993.0	2150.0	0.664933	NO
1987	2193.05	2150.0	0.20871	YES
CAPACITY OF UNIT ADDED = 100.0 MW			O.R.=0.02	AVAIL. = 0.98
1987	2193.05	2250	11.7728	YES
CAPACITY OF UNIT ADDED = 100.0 MW				
1987	2193.05	2350.0	1.7316	YES
CAPACITY OF UNIT ADDED = 100.0 MW			O.R = C.02	AVAIL. = 0.98
1987	2193.05	2450.0	0.62795	NO
1988	2412.35	2450.0	2.13694	YES
CAPACITY OF UNIT ADDED = 100.0 MW			O.R = C.02	AVAIL. = 0.98
1988	2412.35	2550.0	4.5592	YES
CAPACITY OF UNIT ADDED = 100.0 MW			O.R = C.2	AVAIL. = 0.98
1988	2412.35	2650.0	1.4125	NO

2.7.2.2 "B" Percent Unit Addition Criterion

In order to maintain a risk level in a given system within a satisfied value, a simple method is developed. This method is based on the assumption that the size of the unit added to the system must be within a given percentage from the peak load. i.e

Capacity of unit to be added = Y_p

where Y_p = peak load of the system.

= Fraction defined as a percentage of peak load.

Now if the size of the added unit is smaller or equal to Y_p then increase the size to a standered one such that it will be equal or less that Y_p. This method has been applied to study the Iraqi system reserve requirement for the period 1972-90, taking ( ) equal to 0.05. Table (2.14) shows the result of this study starting from 50 MW unit capacity additions. It is seen from the table that more than one unit is required to improve the risk level during one year. This is a disadvantage from the economical point of view.

2.7.2.3 Yearly Increasing Rate Method

Another method is suggested, i.e to determine the proper size of the added unit from reliability point of view.

[illegible] UNIT ADDITION SCHEME.

β = 0.05

	YEAR OF STUDY	PEAK LOAD(MW)	TOTAL CAPACITY(MW)	RISK LEVEL DAYS YEAR	WETHER UNIT ADD.REQUIRED
A.	From 1972-1978 The added Unit is 50 MW as shown in table (2.12)				
B.	1979	1023.07	1050.0	22.829	Yes
	CAPACITY OF UNIT ADDED = 100.0 MW		O.R = 0.02		AVA.= 0.98
	1979	1023.07	1150.0	1.006	No
	1980	1125.38	1150.0	24.4	Yes
	CAPACITY OF UNIT ADDED = 100.0 MW		O.r = 0.02		AVA.= 0.98
	1980	1125.38	1250.0	0.40	NO
	1981	1237.92	1250.0	10.93	YES
	CAPACITY OF UNITS ADDED = 2x100.0 MW		O.R = 0.02		AVA.= 0.98
	1981	1237.92	1450.0	0.485	NO
	1982	1361.71	1450.0	11.359	YES
	CAPACITY OF UNIT ADDED = 100.0 MW		O.R = 0.02		AVA.= 0.98
	1982	1361.71	1550.0	0.349	NO
	1983	1497.88	1550.0	9.45	YES
	CAPACITY OF UNIT ADDED = 100.0 MW		OR = 0.02		AVA.= 0.98
	1983	1497.88	1650.0	0.640	NO
	1984	1647.67	1650.0	16.25	YES
	CAPACITY OF UNIT ADDED = 2 x 160.0 MW		O.R = 0.02		AVA.= 0.98
	1984	1647.67	1850.0	1.044	NO
	1985	1812.43	1850.0	15.044	YES

YEAR OF STUDY	PEAK LOAD(MW)	TOTAL CAPACITY(MW)	RISK LEVEL DAYS/YEAR	WETHER UNIT ADD.REQUIRED
CAPACITY OF UNITS ADDED = 2x100 MW		O.R = 0.02	AVA = 0.98	
1985	1812.43	2050.0	0.58	NO
1986	1993.68	2050.0	17.53	YES
CAPACITY OF UNITS ADDED = 2x100 MW		O.R = 0.02	AVA = 0.98	
1986	1993.68	2250.0	0.583	NO
1987 2	2193.05	2250.0	16.81	YES
CAPACITY OF UNITS ADDED = 2 x100 MW		O.R = 0.02	AVA = 0.98	
1987	2193.68	2450.0	0.595	NO
1988	2412.35	2450.0	13.69	YES
CAPACITY OF UNIT ADDED = 2x150 MW		O.R = 0.02	AVA = 0.98	
1988	2412.35	2750.0	0.274	NO
1989	2653.59	2750.0	15.25	YES
CAPACITY OF UNIT ADDED = 150 MW		O.R = 0.02	AVA = 0.92	
1989	2653.59	2900	0.263	NO
1990	2918.89	2900	22.2	YES
CAPACITY OF UNIT ADDED = 200 MW		O.R = 0.02	AVA = 0.98	
1990	2918.89	3100.0	0.52	NO

Define

C_c = The curtailed capacity in MW.

C_s = The suggested capacity that will improve the risk level after unit addition.

K = a constant rate of increasing (MW).

Then

$$C_s^{New} = C_c^{Old} + K .$$

Now in order to asses this addition technique, it is necessary to apply it to a practical system such as the Iraqi system.

Table (2..15) give the obtained results from running the computer program with application of this method for Iraqi generating system.

It is seen that as the years advances; the unit size will increase according to the previous equation,until there will be no more addition of new units through three or more years. This is practically impossible since the uncertainty in load prediction exists. Hence this method has a limitation as the years of prediction extended to cover a large number of years that the various expansion of load should be considered.

The unit additions for Iraqi system would have to be made in years 72,73,74,75,77,79,82,84,86,88 with capacities of 50,100,150,200,250,300,350,400,450,500 MWrespectivaly.

Table (2.15)

ANNUAL INCREASING RATE METHOD UNIT ADD.SCHEME E=50 MW

YEAR OF STUDY	PREAK LOAD(MW)	TOTAL CAPACITY(MW)	RISK LEVEL DAYS/YEAR	WETHER UNIT ADD.REQUIRED
1972	525.0	550.0	3.61306	YES
CAPACITY OF UNIT ADDED = 50 MW			O.R = 0.02	AVAIL=0.88
1972	525.0	600.0	0.89725	NO
1973	577.50	600.0	2.94698	YES
CAPACITY OF UNIT ADDED = 100 MW			O.R = 0.02	AVAIL = 0.98
1973	577.50	700.0	0.409143	NO
1974	635.24	700.0	4.12736	YES
CAPACITY OF UNIT ADDED = 150.0 MW			O.R = 0.02	AVAIL = 0.98
1974	635.24	850.0	0.2518942	NO
1975	698.77	850.0	1.99045	YES
CAPACITY OF UNIT ADDED = 200.00			O.R = 0.02	AVAIL = 0.98
1975	698.77	1050.0	0.04004	NO
1976	768.65	1050.0	0.16874	NO
1977	845.51	1050.0	1.65681	YES
CAPACITY OF UNIT ADDED = 250		O.R = 0.02		AVAIL = 0.98
1977	845.51	1300.0	0.056568	NO
1978	930.06	1300.0	0.193960	NO
1979	1023.07	1300.0	1.581750	YES
CAPACITY OF UNIT ADDED = 300.0 MW			O.R=0.02	AVAIL = 0.98
1979	1023.07	1600.0	0.0529614	NO
1980	1125.38	1600.0	0.1979083	NO
1981	1237.92	1600.0	1.2528	NO
1982	1361.71	1600.0	5.75225	YES

YEAR OF STUDY	PEAK LOAD(MW)	TOTAL CAPACITY(MW)	RISK LEVEL DAYS/YEAR	WTHER UNIT ADD.REQUIRED
CAPACITY OF UNIT ADDED = 350.0			O.R = 0.02	AVAIL = 0.98
1982	1361.71	1990.0	0.1472156	No
1983	1447.88	1950.0	0.57397	No
1984	1647.67	1950.0	4.35078	YES
CAPACITY OF UNIT ADDED = 400.0			O.R = 0.02	AVAIL =0.98
1984	1647.67	2350.0	0.1453294	No.
1985	1812.43	2350.0	0.5757929	No.
1986	1993.68	2350.0	4.595166	YES
CAPACITY OF UNIT ADDED = 450.0			O.R = 0.02	AVAIL= 0.48
1986	1993.68	2800.0	0.1575165	No
1987	2193.05	2800.0	0.680066	No
1988	2412.35	2800.0	5.53850	YES
CAPACITY OF UNIT ADDED = 500 MW		O.R = 0.02	AVAIL = 0.98	
1988	2412.3	3300.0	0.203513	No
1989	2653.59	3300.0	0.6149	No
1990	2918.95	3300.0	0.99670	No

The variation in the annual risk level is shown by the dotted lines in figs(2.9-12).

It can be concluded that there are no problem of more than one unit addition per year in this method, and this is a big advantage from economical side of view.

2.5 Conclusions and Results:-

The following conclusions and results can be summerised from the study in this chapter.

1. The methods and assumptions concerning the forecast accuracy are the most influential in determining the reserve requirements for any given system.
2. Minor changes in the generator outage rate have little effect on the probability of loss of load. Therefore the outage rate to be chosen for generating units is not a critical value, as long as reasonable estimates are made.
3. The use of excessively large generators will not only improve the risk level of the system but it causes an appriciable increase in the system generating reserve requirements, hence the proper size of generating units to be added for Iraqi system around the year 1985 and after will be of 300 MW output.

4. It is shown from the probability calculations that generating units, up to certain size, may be added to a system without any increase in reserve. Beyond that size moderate increases become necessary, and as the generating unit size continues to increase, greater and greater amount of reserve are needed. A point may be reached where the increased amount of reserve, due to the addition of a usually large generating unit, renders the installation of such unit to be uneconomical.

5. Timing the installation of new generating capacity depends on the amount of generating reserve capacity required. The reserve, in turn, is affected by the size and type of the generating capacity.

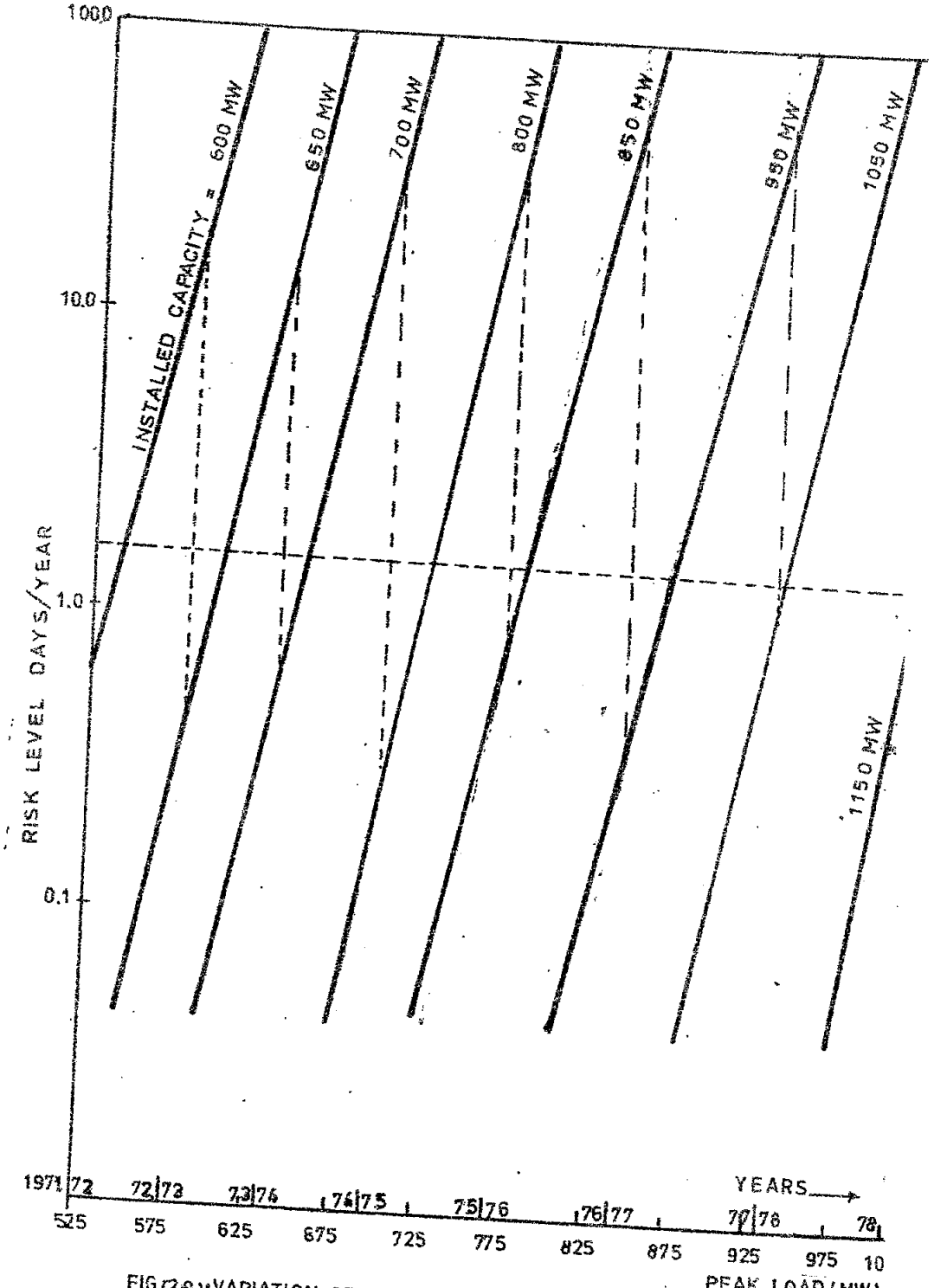


FIG.(2.8): VARIATION OF RISK LEVEL OF IRAQI SYSTEM DUE TO 50 MW UNIT ADDITIONS

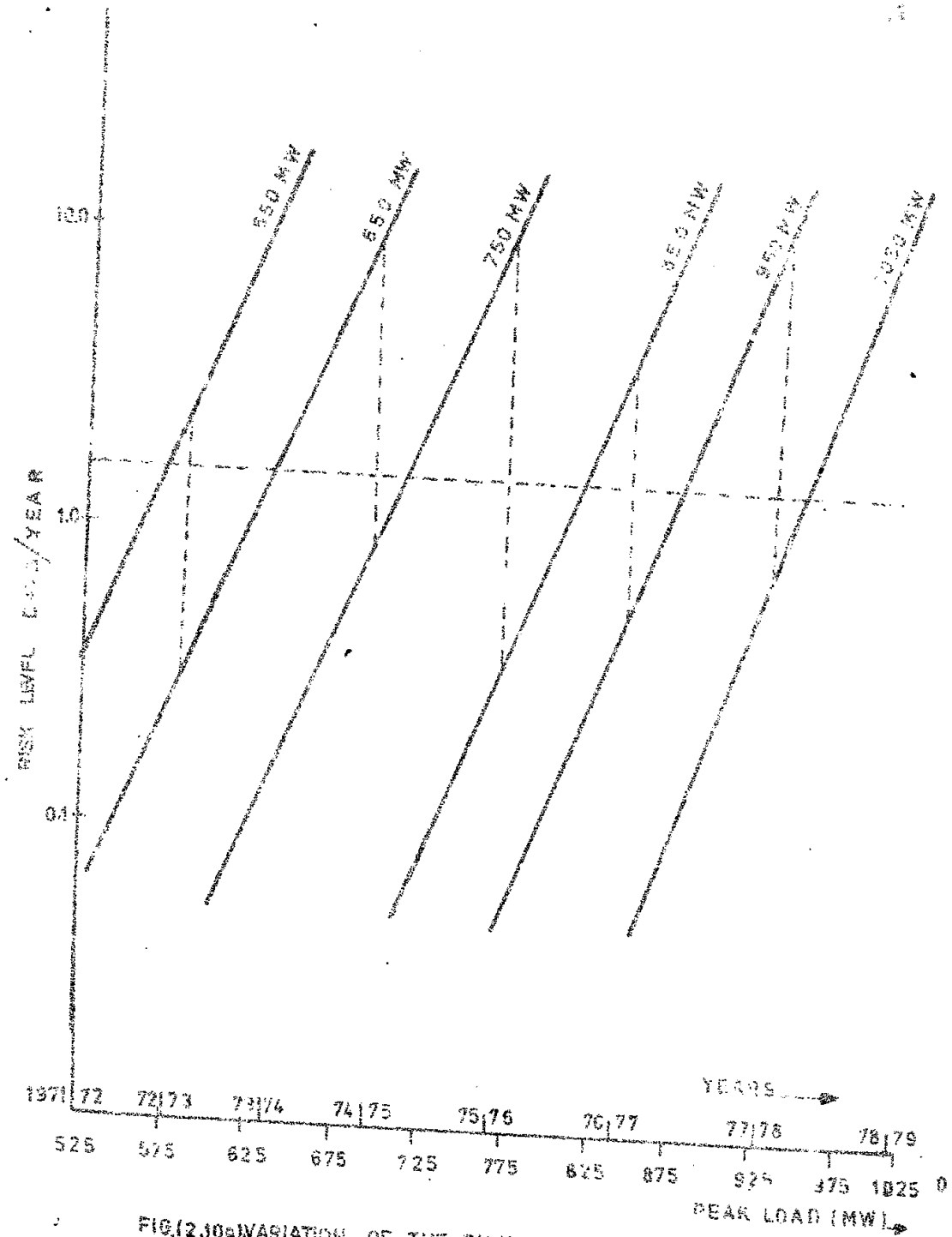


FIG.(2.10a)VARIATION OF THE RISK LEVEL WITH THE VARIATION OF THE PEAK LOAD FOR IRAQI GENERATING SYSTEM (100 MW UNITS ADDITION)

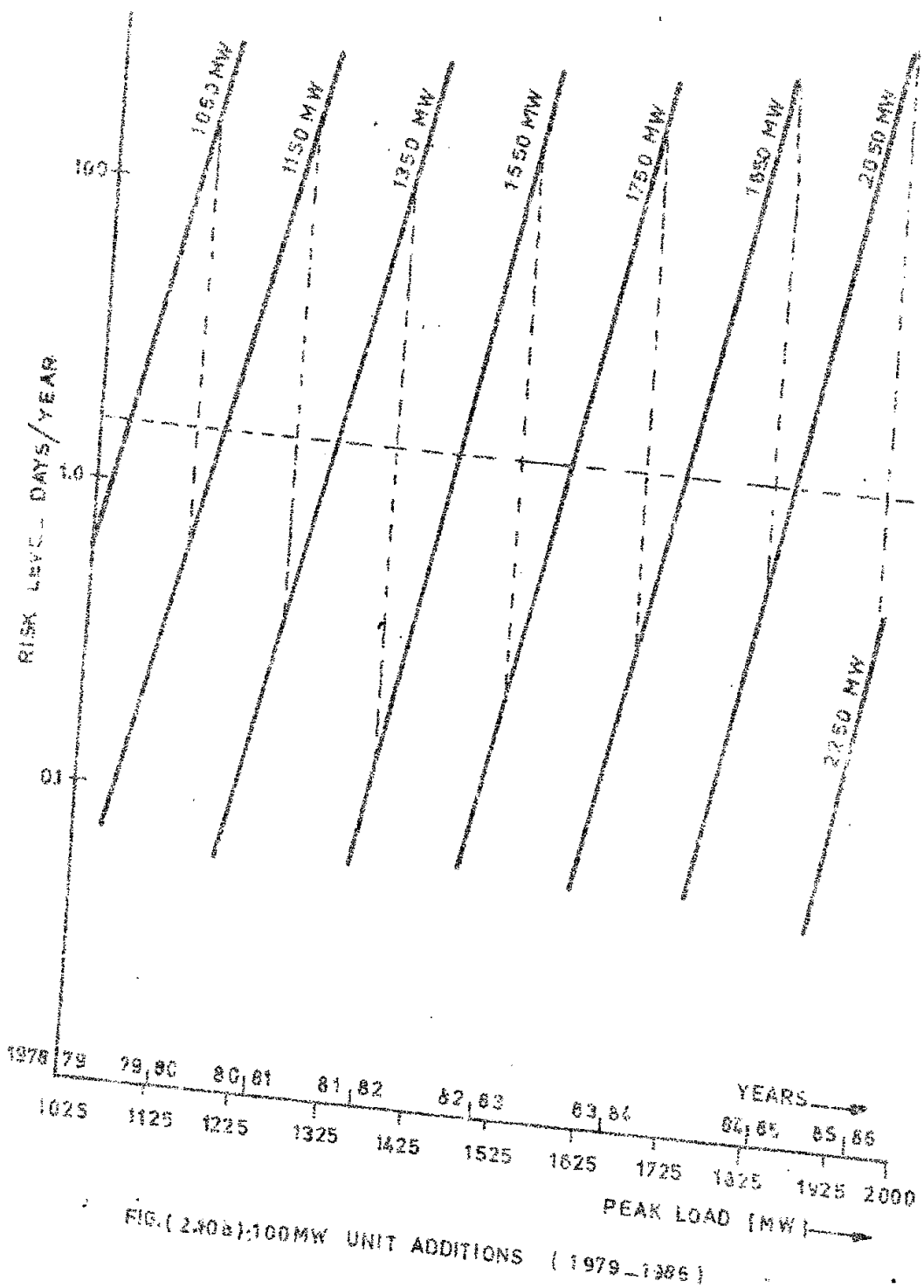
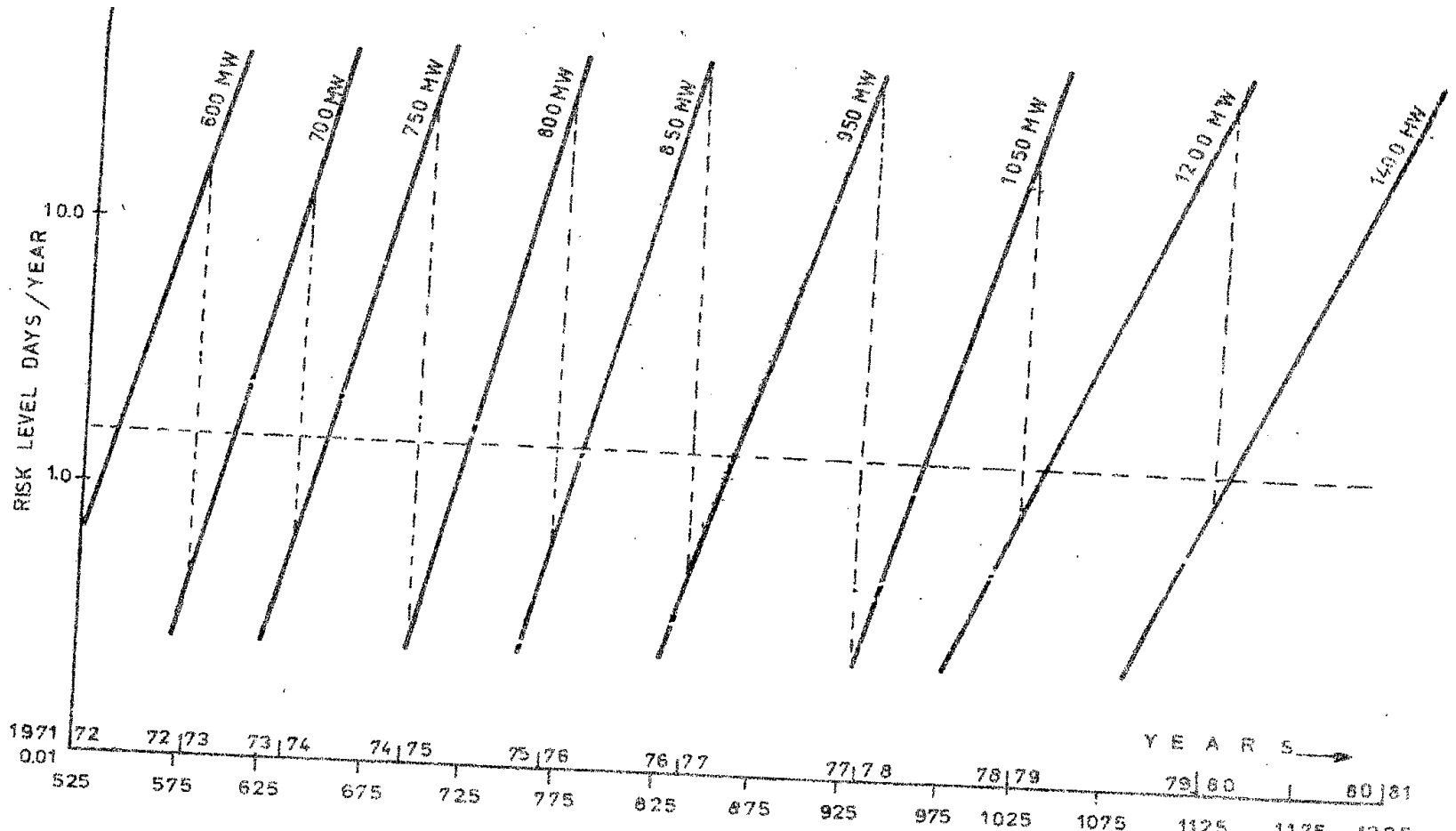
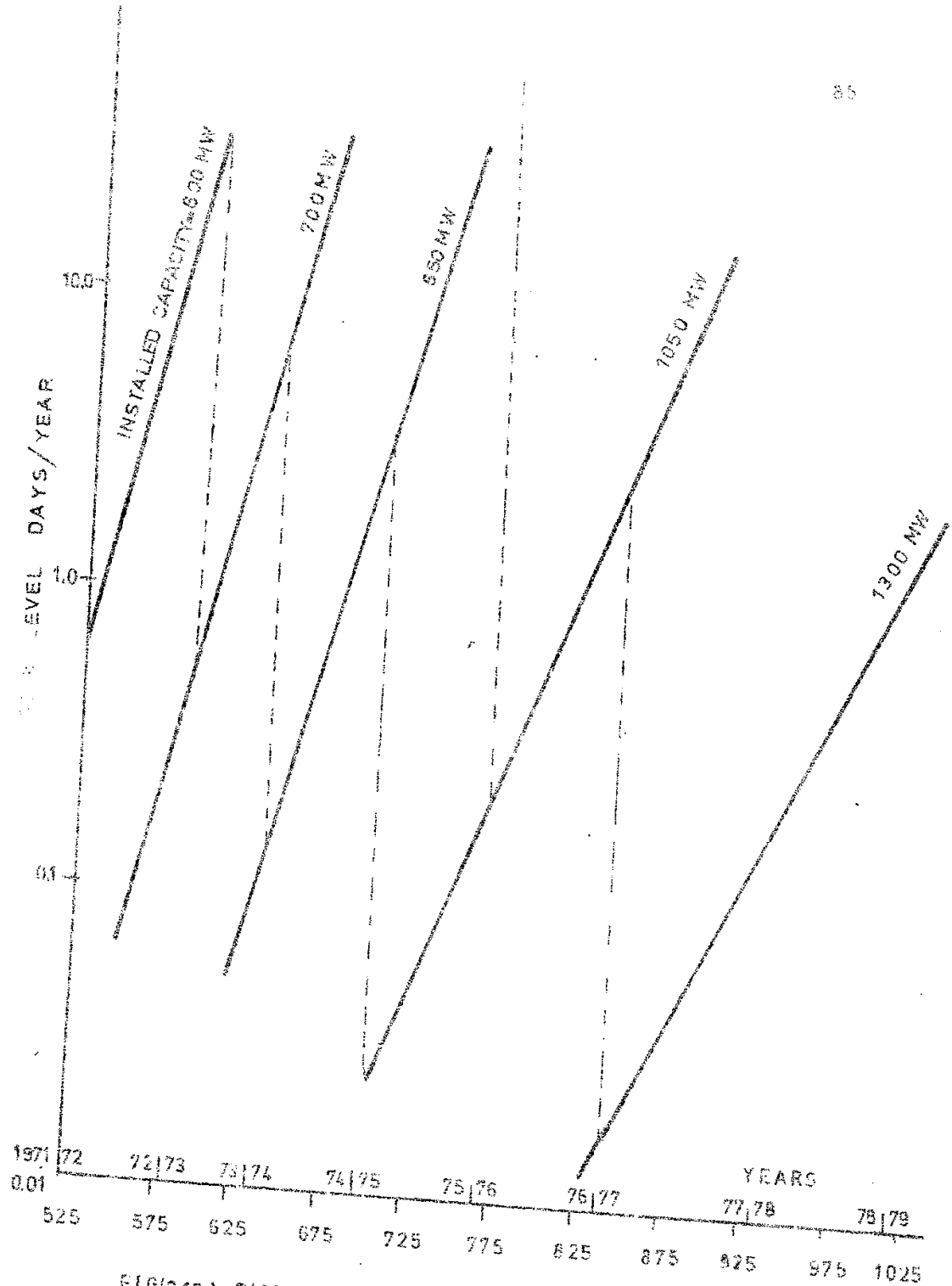


FIG.(2.40a):100MW UNIT ADDITIONS (1979-1986)



FIG(2.11):RISK LEVEL VARIATIONS WITH PEAK LOAD FOR IRAQI N.E.A. SYSTEM OVER 10 YEARS ($\beta = 0.05$)



FIG(2.12): RISK LEVEL VARIATION WITH PEAK LOAD FOR IRAQI N.E.A. SYSTEM — YEARLY INCREASING RATE METHOD WITH K=5.0 MW

PART - II

TRANSMISSION SYSTEM RELIABILITY EVALUATION

List of Symbols

$\lambda_1, \lambda_2, \ldots\ldots, \lambda_n$ = Normal weather Component failure rate, (failures/year) of normal weather.

$\lambda'_1, \lambda'_2, \ldots\ldots, \lambda'_n$ = Stormy weather component failure rate, (failures/year) of stormy weather.

$r_1, r_2, \ldots\ldots, r_n$ = Expected value of repair time for all forced outage (years).

$\lambda''_1, \lambda''_2, \ldots\ldots, \lambda''_n$ = Component maintenance outage rate, maintenance (outage/year).

$r_1, r_2, \ldots\ldots, r_n$ = Expected value for down time due to maintenance outage (years)

N = Expected duration of normal weather (years)

S = Expected duration of stormy weather (years)

n = $1/N$ = rate of encountering normal weather.

m = $1/S$ = rate of encountering Stormy weather

μ = $1/r$ = rate of repair

MTTF = The mean time to failure

[P] = the transitional probability matrix.

[I] = identity matrix.

[W] = truncated matrix

[N] = the fundamental matrix.

$P_o(t), P_1(t), P_2(t), ..P_n(t)$ = the probabilities that a given system is in state, 0,1,2,..n respectively.

$P_o'(t), P_1'(t), P_i'(t), ..P_n'(t)$ = The time derivatives of the above probabilities.

CHAPTER 3

General Methods and Techniques

3.1 The Annual Interruption Rate Method.

Z.G. Todd[17], introduced a simple method for calculating the expected outage frequency and outage duration at any point in any electrical power system transmission or distribution networks. The technique in this method is very easy, and is based on the simple probability mathematical models with the following four assumptions:

1. Each component must be in either of two states, Up(available) or down (Unavailable).
2. The arithmatic consideration of simultaneous occurrence of a number of events.
3. For a series arrangment of facilities, power is to flow only when simultaneous up conditions of components are fullfilled..
4. For a parallel arangement of facilities, power is to flow only when one or more parallel paths are to exist.

In view of these points, some simplifications are made in order to provide a straightforward and applicable formula for any complicated network.

The first point is based on the fact that the outage duration due to maintenance is not considered, i.e assuming only two states, either the component is available or not available.

The probability of a component being unavailable is given by its forced outage rate ' q ' Taking "p" as the availability rate then.

$P + q = 1$

The component failures in the second point are assumed to be independent events and therefore the probability of simultaneous occurrence is given by the product of the individual probabilities.

For series arrangment the success of system operation needs all the components to be in the up state or available Any failure of a component will cause the failure of the entire system. Thus, from the well known chain formula, the availability of any system containing n series component is given by

$$P_s = \prod_{i=1}^{n} P_i \qquad \ldots\ldots(3.1)$$

or $P_s = P_1 \cdot P_2 \cdot P_3 \ldots\ldots P_n$

For the case of two units in series

$$P_s = P_1 P_2$$

and $q_s = 1 - P_s$

$$= 1 - P_1 P_2 = q_1 + q_2 - q_1 q_2 \qquad \ldots\ldots(3.2)$$

Now, in practice, for any component of a transmission system, q_1 and q_2 are a small fraction that the quantity $(q_1 \cdot q_2)$ is very small, hence equation(3.2) can be approximated to

$$q_s = q_1 + q_2 \qquad \ldots\ldots(3.3)$$

i.e in general for a two series transmission components the failure probability is given by the sum of the element failure probabilities.

The last point is that for a parallel system, all paths must fail for system failure. And as the number of parallel paths is increased, the probability of simultaneous outage of all paths decrease . Thus from the well-known formula of parallel arrangement of system failure.

$$q_s = \prod_{i=1}^{n} q_i \qquad \ldots\ldots(5.4)$$

$\therefore$ $q_s = q_1 \cdot q_2$ for two component in parallel.

The outage frequency and outage duration at each paint in an electrical network can be evaluated by considering the electrical forced outage rate of any component in the system. This may be defined as the component outage time that stays in the failure state divided by the total component exposure time. This gives the probability of component outage rate ; thus:

$$q = \frac{\text{Sum of the days upon which an outage of specified minimum duration occured}}{\text{Sum of unit days}}$$

and A.A.C.I.R = Annual Average Consumer Interruption Rate.

= The expected number of days in a year the outage condition for any point will occur for the load.

Hence

$$A.A.I.R = q_s \cdot 365 \quad \text{Days/year} \quad \ldots\ldots(5.5)$$

where q_s is the resultant unavailability between the load point and the generating points.

It seems, from the above discussion, that this approach is straightforward and easy to apply, but it is not sufficiently accurate for the evaluation of reliability measures. for any given system due to the following reasons:

1. The effect of fluctuating environment due to storms and other weather conditions that may cause a failure in the system component are not considered.
2. The scheduled outages such as maintenance or network extension are not considered.

As far as these reasons are concerned this method is restricted to the evaluation of continuity of supply at any required point, and cannot be applied or extended to systems that are not fully redundant.

3.2 Frequency and Duration Approach (Approximate Method)

This method[18] is a simplified approach to transmission system reliability evaluation considering two-state fluctuating environment (normal, and stormy weather) effect.

The method is based on series-parallel reduction technique which reduces the subunits to an approximate equivalents, and calculate outage frequency and outage duration. The following assumptions are involved:-

1. The system consist of discrete states that are behaving independently and randomly.
2. The period between failure and repair time and also the duration period of normal and stormy weathers are random variables with exponential probability distribution.
3. Repair times are typically very short compared with time of failure and times between storms.
4. The stormy period are very short compared with time of failure for component.
5. Only one component fails at a time.
6. The distribution of maintenance down times are exponential.
7. The parallel arangment facilities are assumed to be fully redundant.
8. Two-state fluctuating environment are considered: normal and stormy weather conditions.

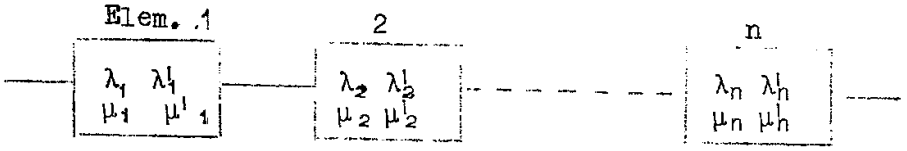
Based on the above assumptions, the method gives an approximate formula for calculating the over all,forced outage rate (normal and stormy weather) for series and parallel systems.

The more complicated systems are reduced step by step to an equivalent series parallel arrangement. Using equations and formulas given by this method which will be explained in the following subsection.

3.2.1 Approximate Formula For Series Systems

Consider a system consisting of n dissimilar components as shown in figure(3.1). Using the parameter definitions, the overall failure rate λ_{fj} for any component "j" is given by the following approximate formula: -

$$\lambda_{fj} = \frac{N}{N+S}\ \lambda_j + \frac{S}{N+S}\ \lambda'_j \quad \text{outage/year} \qquad \ldots\ldots(3.6)$$



Figure(3.1) Series Configuration

The error due to the approximation in this formula is usually small and can be neglected. An exact formula may be obtained from stochastic approach using Markov Continuous technique; which will be discussed later on in details.

The over all forced outage rate of a series system is given by :

$$\lambda_{fe} = \sum_{j=1}^{n} \lambda_{fi} \quad \text{(outages/year)....(3.7)}$$

and maintenance outage. rate :

$$\lambda_e^{(1)} = \sum_{j=1}^{n} \lambda_j^{(1)} \text{ (Maintenance Outage/year)..(3.8)}$$

If the series system given in figure(3.1) is considered as only one equivalent component that connects the power Source to a given load, then the reliability indices for the load would be calculated as follows:

Outage Rate:

$$\lambda_s = \lambda_{fe} + \lambda_e^{(1)} \quad \text{outage/year.}$$

Expected outage duration

$$r_s = \frac{\sum_{i=1}^{n} \lambda_{fi} \cdot r_j + \sum_{i=1}^{n} \lambda_j \cdot r_j}{\lambda_s} \text{ years ...(3.9)}$$

Average total outage time in one year:

$$U_s = \frac{rs}{rs + 1/\lambda_s} \lambda_s . r_s \quad \text{years/years.}$$

$$= 8760. \lambda_s . r_s \quad \text{Hours/year...(3.10)}$$

It is noticed that the maintenance outages is treated as a random event, but practically the maintenance outage is not randomly performed, but occurs at a pre-determined time. Hence the above equations can be rewritten without considering maintenance as a random parameter as stated by R.Billinton[12] and given in table (3.1); -

Table(3.1): Modified Series Equivalent Formulae

Annual outage Rate outage/year	$\lambda_{fe} = \sum_{j=1}^{n} \lambda_{fi}$
Expected outage Duration (Years)	$r_{fe} = \frac{\sum_{j=1}^{n} \lambda_{fi} r_j}{\lambda_{fe}}$
Average total time per year (Hours)	$U = 8760. \lambda_{fe} r_{fe}$

3.2.2 Approximate Formula For parallel System

As it have been mentioned previously that this method can be applied only for two components in parallel; three or more components in parallel may be reduced by successive operation to two components in parallel before this method is applied.

In order to obtain an approximate expressions for the yearly outage rates for parallel component four seperate phases must be considered as follows:-

a. phase I: the first failure occurs during normal weather; and the second also occurs during normal weather.

b. Phase II: the first failure occurs during normal weather; while the second occurs during stormy weather.

c. phase III: both first and second failures occur during stormy weather.

d. phase IV : The first failure occurs during stormy weather and the second occurs during normal weather.

Now assuming no outages due to maintenance and overloading, the simplified approximate method gives the following expressions for parallel system overall outage rate:

Phase I :

$$\lambda_1 = \frac{N}{N+S}\left[\lambda_1\left(1-\frac{r_1}{N}\right).(\lambda_2 r_1) + \lambda_2\left(1-\frac{r_2}{N}\right).(\lambda_1 r_2)\right] \quad ..(3.11)$$

Phase II :

$$\lambda_{II} = \frac{N}{N+S}\left[\lambda_1\left(\frac{r_1}{N}\right).(\lambda'_2.S) + \lambda'_2\left(\frac{r_2}{N}\right).\lambda'_1.S \right] \quad ..(3.12)$$

Phase III :

$$\lambda_{III} = \frac{S}{N+S}\left[\lambda'_1.(S.\lambda'_2) + \lambda'_2.(S.\lambda'_1)\right] \quad ....(3.13)$$

Phase IV :

$$\lambda_{IV} = \frac{S}{N+S}\left[\lambda'_1.(1-S\lambda'_2).(\lambda_2 r_1) + \lambda'_2(1-S\lambda'_1).(\lambda_1 r_2) \right]$$

$$.....(3.14)$$

In practice, usually the repair times r_1 and r_2 are very small compared with the normal period N, hence the above expressions may be reduced to a more simpler form. Also in phase(II) the probability of failure of component number(2) during sotrmy weather period ($S\lambda'_2$) is much smaller than unity.

The expression for λ_{IV} can be approximated also. Thes approximation for phase I and phase IV are:

$$\lambda_I = \frac{N}{N+S}\left[\lambda_1 \lambda_2 (r_1 + r_2)\right] \quad \ldots\ldots(3.15)$$

$$\lambda_{IV} = \frac{S}{N+S}\left[\lambda'_1 \lambda_2 r_1 + \lambda'_2 \lambda_1 r_2\right] \ldots(3.16)$$

These expressions for the four phases may be summed up in a general expression as follows:

$$\lambda_T = \frac{N}{N+S}\left[\lambda_1 \lambda_2 (r_1+r_2) + \frac{S}{N}(\lambda_1 \lambda'_2 r_1 + \lambda_2 \lambda'_1 r_2) + \frac{S}{N}(\lambda'_1 \lambda_2 r_1 + \lambda'_2 \lambda_1 r_2) + \frac{2S^2}{N} \lambda'_1 \lambda'_2\right]$$

$\ldots.(3.17)$

Equation (3.17) is used to calculate the reliability indices for any given system which suffer from two state fluctuating environment.

This technique is an extremely important one, because its development is a big step forward in quantitative transmission system reliability evaluation.

3.3 The Exact Markov Method (19)

The reliability evaluation of transmission system using the probability theories and Boolean algebra techniques becomes limited or unapplicable when the repair time of an elements in the system is considered. The element in a repairable system will have a restoring time for repair.

In this case renewel theory and Markov process are applied.

The transmission system, as a part of a power system are widely branched, has great length, operates under variable weather conditions, and is subjected to the action of atmospheric disturbances of either electrical nature or other factors. Hence it is important to consider their reliabilities under normal and stormy weather conditions.

The Markov Technique which is based on the state space concepts and stochastic processes gives an accurate method for reliability evaluation for such systems.

3.3.1 Markov Processes[20]

There are two types of Markov processes:

i. A process that is discrete in space and time.

ii. A process that is discrete in space and continuous in time.

The processes themselves have states which are characterized by two conditions ; discrete and continuous. Usually, there is a transition rate from one state to another inside each process.

When this transition is constant the Markov process is said to be stationary; while, if the transition rate is not constant, the process is said to be non-stationary or non Markovian process.

The reliability problems normally deal with repairable systems that are discrete in space but continuous in time.

3.3.2 Mathematical Background

Now consider the case of a single element which exists in two states whose state space diagram is shown in figure (3.2).

The failure and repair rates of such an element are characterized by exponential distributions.

After an incremental time interval (dt), the probability of two or more events occurring during this increment of time is negligable, thus for two state case, either failure or operation (0 and 1) are given by :

$$P_0(t+dt) = P_0(t)(1- \lambda dt)+P_1(t)(\mu .dt) \quad \ldots(3.18)$$

and

$$P_1(t+dt) = P_1(t)(1-\mu .dt)+P_0(t)(\lambda .dt) \quad \ldots(3.19)$$

for the above equations :

$$\frac{P_0(t+dt) - P_0(t)}{dt} = - \lambda . P_0(t) + \mu . P_1(t).$$

or $$\left.\frac{P_0(t+dt) - P_0(t)}{dt}\right|_{dt \to 0} = \frac{dP_0(t)}{dt} = P_0'(t)$$

In matrix form :

$$\begin{bmatrix} P_0'(t) \\ P_1'(t) \end{bmatrix} = \begin{bmatrix} P_0(t) & P_1(t) \end{bmatrix} \begin{bmatrix} -\lambda & \lambda \\ \mu & -\mu \end{bmatrix} \quad \ldots(3.20)$$

Solving for intial conditions, i.e when t=0, thus :

$$P_0(t) = \mu/(\mu + \lambda) + e^{-(\mu+\lambda)t}/(\mu+\lambda) \quad ....(3.21)$$

$$P_1(t) = \lambda/(\mu + \lambda) + e^{-(\mu+\lambda)t}/(\mu+\lambda) \quad ....(3.22)$$

However, as $t \to \infty$ this become :

$$P_0(\infty) = \mu/(\mu+\lambda) = \text{availability} \quad .....(3.23)$$

$$P_1(\infty) = \lambda/(\mu+\lambda) = \text{Unavailability} \quad .....(3.24)$$

In more complicated systems it becomes very difficult to obtain a general expression for these two measures. This is illustrated in the next case of simple two unit system.

3.3.3 Single Element Case With Two-States Fluctuating Environment Conditions

Although the approximate method, which is based on treating the element encountering two-states fluctuating environment in phase style, the Markov technique gives an accurate evaluation for reliability of such an element.

Before proceeding to construct the transitional probability matrix [P] ; the state diagram must be constructed. The diagram for single element with two-State fluctuating environment is shown in figure(3.3)

Starting directly from the state space diagram; the differential equation matrix can take the following form

$$\begin{bmatrix} P_0'(t) \\ P_1'(t) \\ P_2'(t) \\ P_3'(t) \end{bmatrix} = \begin{bmatrix} P_0(t) & P_1(t) & P_2(t) & P_3(t) \end{bmatrix} \begin{bmatrix} -(\lambda+n) & n & \lambda & 0 \\ m & -(m+\lambda') & 0 & \lambda' \\ \mu & 0 & -(\mu+n) & n \\ 0 & \mu' & m & -(\mu'+m) \end{bmatrix}$$

.....(3.25)

Now the availability or the steady state probability is obtained as the time period becomes large, i.e as $t \to \infty$. Hence the above matrix equation gives a steady state solution by setting all time derivatives to zero as follows : -

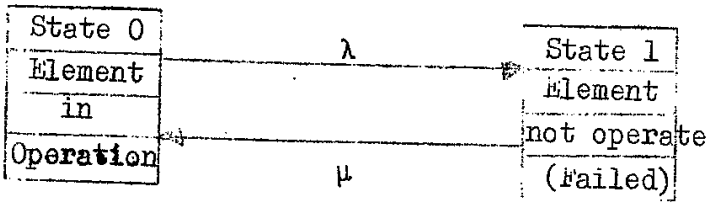
$$-(\lambda+n)P_0 + mP_1 + \mu P_2 = 0$$

$$n P_0 - (m+\lambda')P_1 + \mu' P_3 = 0$$

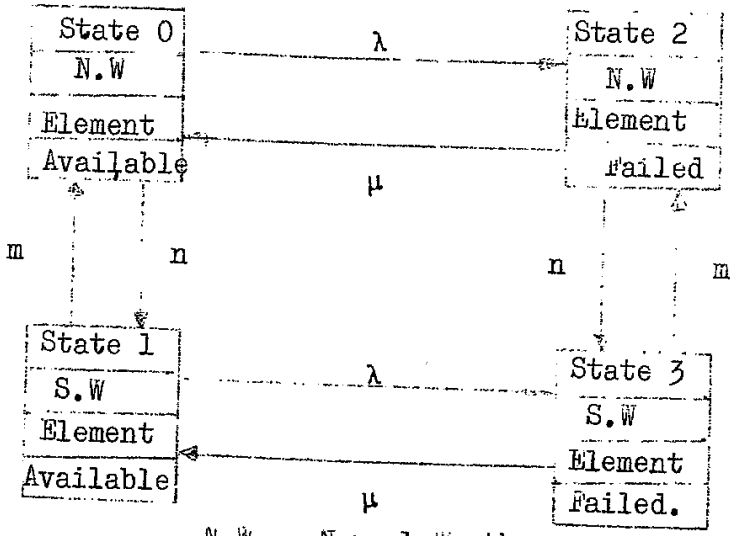
$$\lambda P_0 - (\mu+n)P_2 + mP_3 = 0$$

$$\lambda' P_1 + n P_2 - (\mu'+m)P_3 = 0$$

where $P_0 + P_1 + P_2 + P_3 = 1.0$



Fig(3.2): State Space Diagram of single Element.



N.W. = Normal Weather

S.W = Stormy Weather

Fig.(3.3) State Space Diagram for Single Element with 2-State Fluctubing Environment.

Hence for this system

P(system operating) =Availability = $P_0 + P_1$

P(System failed) = Unavailability= $P_2 + P_3$

If the repair time is assumed to be independent of the environment; i.e $r = r'$ or $\mu = \mu'$.

Thus

$$P(\text{system operating}) = \frac{\mu[(m+n)^2+m(\mu+\lambda')+n(\lambda'+\mu)]}{M+n[(\mu+\lambda).(\mu+\lambda')+m(\mu+\lambda)+n(\mu+\lambda')]}$$

$$P(\text{system Failed}) = \frac{1}{m+n}\left[\frac{n\lambda'(n+\mu)+m\lambda(m+\mu)+nm(\lambda+\lambda'+\mu)+\lambda\lambda'(m+n)}{(\mu+\lambda).(\mu+\lambda')+m(\mu+\lambda)+n(\mu+\lambda')}\right]$$

Considering the normal weather case only ...(3.27)

i.e $\lambda' = 0$, $m = 1$, $n = 0$

$$\text{Availability} = \frac{\mu}{\mu+\lambda} \qquad \ldots\ldots(3.28)$$

$$\text{Unavailability} = \frac{\lambda}{\mu+\lambda} \qquad \ldots\ldots(3.29)$$

These results is obtained in equation (3.23),(3.24) in the previous subsection.

In general the system reliability is not given by the availability of its parts only but with other reliability indices which are

a. The mean time to failure (MTTF)

b. The average failure Rate

The MTTF of single element case is found by deleting both the absorbing states 2 and 3 from the stochastic transitional probability Matrix. [z]

This matrix is given as follows.

$$[z] = \begin{array}{c} \\ 0 \\ 1 \\ 2 \\ 3 \end{array} \begin{array}{c} \begin{array}{cccc} 0 & 1 & 2 & 3 \end{array} \\ \begin{bmatrix} 1-(\lambda+n) & n & \lambda & 0 \\ m & 1-(m+\lambda') & 0 & \lambda' \\ \mu & 0 & 1-(\mu+n) & n \\ 0 & \mu' & m & 1-(\mu'+m) \end{bmatrix} \end{array} \quad ..(3.30)$$

The matrix which is formed by deleting states 2 and 3 is known as the truncated matrix[W] and is given as follows:

$$[W] = \begin{array}{c} \\ 0 \\ 1 \end{array} \begin{array}{c} \begin{array}{cc} 0 & 1 \end{array} \\ \begin{bmatrix} 1-(\lambda'+n) & n \\ m & 1-(m+\lambda') \end{bmatrix} \end{array} \quad .....(3.31)$$

The fundamental matrix N is

$$[N] = [I-W]^{-1} = \frac{1}{D} \begin{bmatrix} m+\lambda' & n \\ m & \lambda+n \end{bmatrix} \quad ....(3.32)$$

where $D = \lambda\lambda' + \lambda m + \lambda' n$.

$$\text{Thus : MTTF} = \frac{m + \lambda' + n}{D} \qquad \ldots\ldots(3.33)$$

and the average failure rate $\lambda_{av} = 1/\text{MTTF}$

and so

$$\lambda_{av} = \frac{D}{m + \lambda' + n} \qquad \ldots\ldots(3.34)$$

3.3.4 Application of Markov Approach to Multi-Element Systems (19)

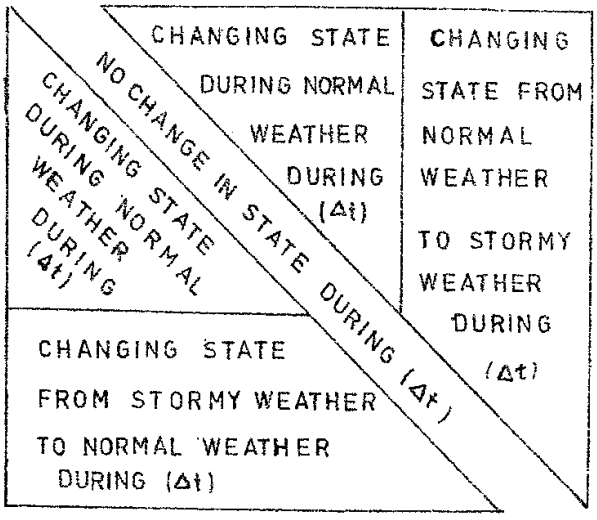
In order to obtain an expression for equivalent rate of failure of a multi-element system; the same procedure for a single unit case is followed. The differential equation of the multielement system will be in the form :

$$[\dot{P}(t)] = [Q][P(t)] \qquad \ldots\ldots(3.35)$$

Using same definitions and assumptions as for single element case, the stochastic transitional probability matrix of two element case using Markov approach on condition that the elements are not repaired during stormy weather period;

i.e $\mu' = 0$, thus : -

$$[P] = \left[\right.$$


CHANGING STATE DURING NORMAL WEATHER DURING (Δt)
CHANGING STATE FROM NORMAL WEATHER TO STORMY WEATHER DURING (Δt)
NO CHANGE IN STATE DURING (Δt)
CHANGING STATE NORMAL WEATHER DURING (Δt)
CHANGING STATE FROM STORMY WEATHER TO NORMAL WEATHER DURING (Δt)

$\left.\right]$

So for two unit case, the state space diagram is shown in fig.(3.4); the [P] matrix is

$$[P] = \begin{array}{c} \\ 0 \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{array} \begin{array}{c} \begin{array}{cccccccc} 0 & 1 & 2 & 3 & 4 & 5 & 6 & 7 \end{array} \\ \left[\begin{array}{cccccccc} 1-\lambda_1-\lambda_2-n & \lambda_2 & \lambda_1 & 0 & n & 0 & 0 & 0 \\ \mu_2 & 1-\mu_2-n-\lambda_1 & 0 & \lambda_1 & 0 & n & 0 & 0 \\ \mu_1 & 0 & 1-\lambda_1-\lambda_2-n & \lambda_2 & 0 & 0 & n & 0 \\ 0 & \mu_1 & \mu_2 & 1-\mu_1-\mu_2-n & 0 & 0 & 0 & n \\ m & 0 & 0 & 0 & 1-\lambda_1'-\lambda_2'-m & \lambda_2' & \lambda_1' & 0 \\ 0 & m & 0 & 0 & 0 & 1-\lambda_1'-m & 0 & \lambda_1' \\ 0 & 0 & m & 0 & 0 & 0 & 1-\lambda_2'-m & \lambda_2' \\ 0 & 0 & 0 & m & 0 & 0 & 0 & -m \end{array}\right] \end{array}$$

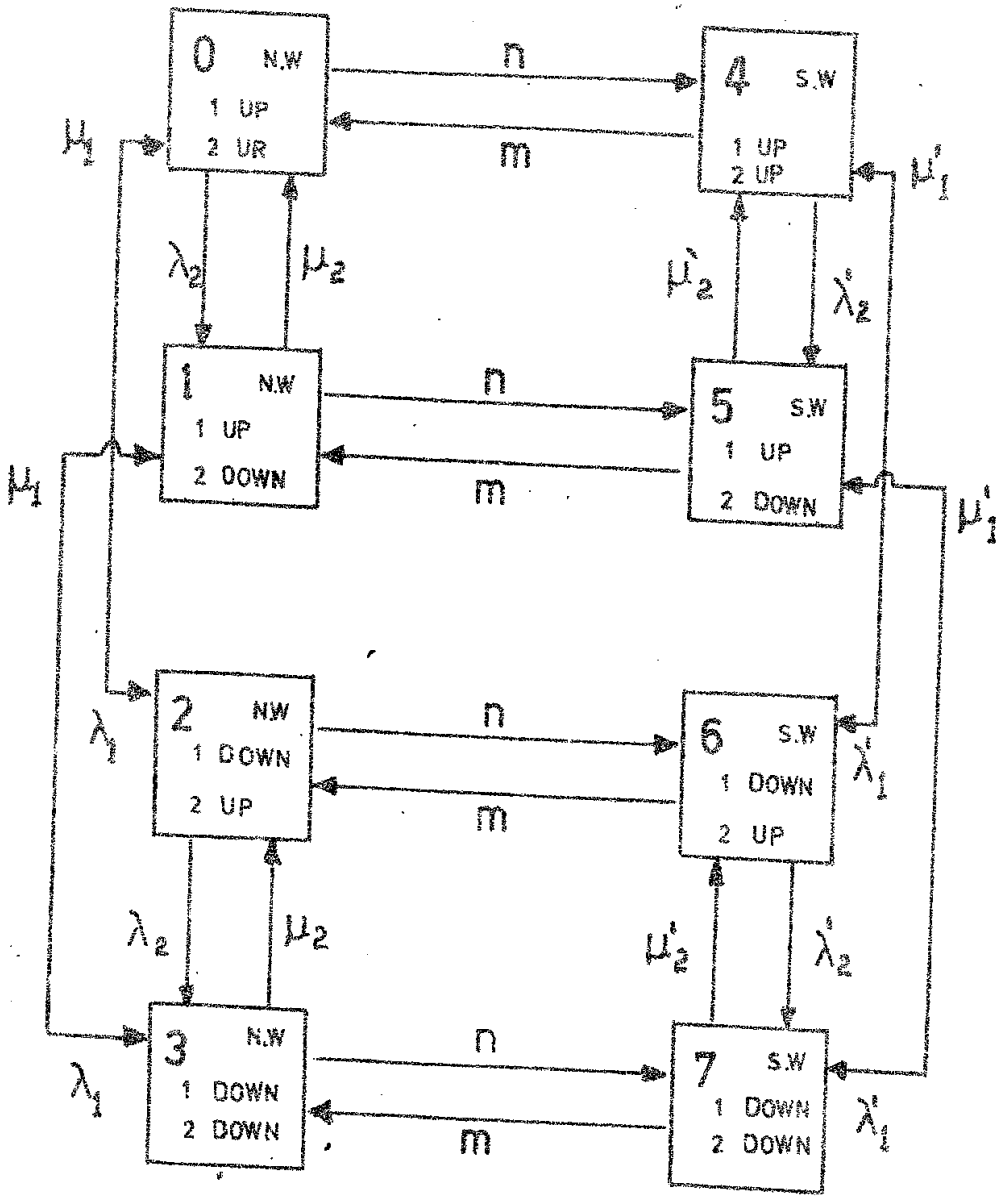


FIG.(3.4): STATE SPACE DIAGRAM FOR TOW UNIT CASE INCLUDING 2-STATE WEATHER CONDITION
N.W=NORMAL WEATHER S.W= STORMY WEATHER

If

$[Q]$ is the transpose of $[P - I]$ matrix, hence:

$[Q] = [P-I]_t$.

So the differential equation given in the following form

$$[\dot{P}(t)] = [P-I]_t \; [P(t)]$$

In order to obtain the MTTF of the system of two elements, the configuration of the system must be considered so that the system failed state or absorbing state are decided previously in order to obtain the truncated matrix $[W]$ where its inversion gives the MTTF of the system starting from any required state as done previously for single element case.

The configuration of the system may be either series or parallel, and these two cases will be discussed for two-element case in details here in after; so that an equivalent model is obtained.

3.3.5 Case of Two-Elements In Series Considering Two-State Weather

a. Availability of the system can be obtained by solving the matrix equation $[\dot{P}(t)] = [Q][P(t)]$ setting all time derivatives to zero and in equation

$P_0 + P_1 + P_2 + P_3 + P_4 + P_5 + P_6 + P_7 = 1.$

Therefore

$$\text{Availability} = A_s = P_0 + P_4 \quad \ldots\ldots(3.37)$$

b. MTTF of two series elements system is obtained by truncating the stochastic transitional probability matrix [H], given in equation (3.36) by eliminating the absorbing states 1 and 3 and 5 and 7, hence if one start from state (0) of the inverse of the truncated matrix , then the MTTF of the system is given by :

$$_oM_s = \frac{\lambda'_1 + \lambda'_2 + m + n}{(\lambda_1 + \lambda_2)(\lambda'_1 + \lambda'_2 + m) + n(\lambda'_1 + \lambda'_2)} \quad \ldots.(3.38)$$

and the average failure rate of the system $\lambda_{av.s}$ is given by

$$\lambda_{av.s} = 1/_oM_s \quad \ldots\ldots(3.39)$$

c. The equivalent system repair rate can be obtained from the fact that for exponentially distributed MTTF and repair time, the value of the unavailability of a given system is simply the equivalent ratio of failure rate and repair rate values, then : -

$$\bar{A}_s = \lambda_{av.s} / \mu_{av.s} \qquad \ldots\ldots(3.40)$$

where $\mu_{av.s}$ is the equivalent repair rate value for series configuration or

$$\bar{A}_s = 1 - A_s, = \lambda_{av.s} / \mu_{av.s}$$

$$\text{then} \quad \mu_{av,s} = \lambda_{av.s} / (1 - A_s) \ldots\ldots(3.41)$$

3.3.6 Case of Two-Units in parallel Considering Two-State Weather

a. Availability may be found by considering first the unavailability of the system which is at absorbing state 3 and 7; $\bar{A}_p$ and then the availability may be found as follows:

$$\bar{A}_p = \bar{A}_3 \cdot \bar{A}_7$$

$$A_p = 1 - \bar{A}_p$$

b. MTTF of a system with two elements in parallel is obtained by truncating the stochastic probability matrix [P] and by eliminating the absorbing states and then finding the inversion of the truncated matrix [W] after subtracting the matrix [I] from it. This may be given in the following equations:

Let [B] be the general matrix which is obtaind as :

$$-[B] = [I-W]_{,} = -\begin{bmatrix} b11 & B_{12} & b_{13} & \cdots & b_{1x} \\ b_{21} & b_{22} & b_{23} & \cdots & b_{2x} \\ \cdots & \cdots & \cdots & & \cdots \\ \cdots & \cdots & \cdots & & \cdots \\ b_{r1} & b_{r2} & b_{r3} & & b_{rx} \\ \cdots & \cdots & \cdots & & \cdots \\ \cdots & \cdots & \cdots & & \cdots \\ b_{x1} & b_{x2} & b_{x3} & \cdots & b_{xx} \end{bmatrix} \quad \ldots.(3.42)$$

and let [c] be the inverse matrix of [B] .

$$[C] = [-B]^{-1} = \begin{bmatrix} C_{11} & C_{12} & C_{13} & \cdots & C_{1x} \\ C_{21} & C_{22} & C_{23} & \cdots & C_{2x} \\ \cdots & \cdots & \cdots & & \cdots \\ \cdots & \cdots & \cdots & & \cdots \\ C_{r1} & C_{r2} & C_{r3} & \cdots & C_{rx} \\ \cdots & \cdots & \cdots & & \cdots \\ \cdots & \cdots & \cdots & & \cdots \\ C_{x1} & C_{x2} & C_{x3} & & C_{xx} \end{bmatrix} \quad \ldots\ldots(3.43)$$

The MTTF of rth State is given by

$$_{r}M_{p} = C_{r1} + C_{r2} + C_{r3} + \ldots + C_{rx} \quad \ldots\ldots(3.44)$$

Hence the average failour rate is given by

$$\lambda_{av.p} = 1/{}_{r}M_{p}$$

$$= 1/(C_{r1} + C_{r2} + C_{r3} + \ldots C_{rx}) \quad \ldots\ldots(3.45)$$

c. The equivalent average repair rate of two elements in parallel μ_{avp} is obtained also from the fact that;

$\bar{A}_p = \lambda_{avp} / \mu_{avp}$.

Thus $\mu_{avp} = \lambda_{avp} / \bar{A}_p \quad \ldots\ldots(3.46)$

It is observed from previous analysis that the complete Markov approach is easily applied to relatively small systems. However, it is very difficult to obtain general expressions even for small systems.

The digital computer provides an easy and accurate numerical solution for this problem.

Again the Markov approach depends upon exponential distribution, so any other distribution may lead to extreme complication even for very small systems.

It should be noticed also that all the above analysis are based on full redundancy and continuity of supply criteria.

CHAPTER 4

Iraqi 132 K.V Transmission System Reliability Evaluation

4.1 Introduction

The studies of transmission system reliability are of great interest in electrical power systems, where increased attention is directed for transmitting the electrical power from the generating sources to the industrial consumers through a reliable transmission system in order to satisfy their needs of continous and reliable supply.

The work presented in this chapter deals with the methods and techniques for transmission system reliability evaluation and their application to a practical system, such as the Iraqi national grid. The lines and equipments reliability measures for this system are of primarily needs in order to start this study; These information are not available or figured out previously ; a tremendous statistical study is done to obtain these measures and then examine the system failure characteristics and the effect of fluctuating environment on these failures.

A partial Correlation study is also done to find the correlation coefficients between the meterological phenomena and temporary outages in the three main regions of Iraq. The reliability indices for all transmission lines

and equipments are calculated from the analysis of historical data using the available digital computer for a period of five years.

The Markov concept which gives an accurate method for reliability evaluation of repairable system considering the 2-state fluctuating environment is applied, in this work, for evaluating the reliability measures under normal and stormy weather conditions for two typical parallel lines in Iraq, connecting Nassiriya-shuaiba substations.

The frequency and duration method is also used to evaluate the reliability measures for the same line and the results are compared with those obtained using the Markov approach.

The effect of variation of failure rates and repair rate of the individual lines on the total mean time to failure and outage rate of the system using the Markov method is also studied.

4.2 Physical system Description

Iraqi 132 K.V transmission system mainly consists of short and moderate length transmission lines carried on single towers with either single or double circuit arrangements. A relatively short lines connecting the power stations and substations inside Baghdad area are considered as

a tie lines. The 132 K.V. transmission potential is steped down to the service voltage by means of step down substations, which consist of transformer banks and switchgear and isolators arrangements.

Table(4.1) gives the technical specifications of 132 K.V. overhead lines for N.E.A system. The system is sectionalized into three sections in accordance with the three main regions of Iraq, namly, the Northern, Central and southern regions. Each parallel component in the system is assumed to be fully redundant; and no problem due to maintenance or overloading are concerned. The criteria of continuity of supply is used in all the analysis of this study.

Fig.(4.1) shows the main connections of the system as givem in single line diagram. It is seen that the three regions are interconnected with each other.

4.3 Forced outage Failures Data and Analysis

The problem of forced outage failures on the transmission system in Iraq has gained little attention as a field of scientific research. The only source of information pertaining to these problems is the N.E.A. dispatching centre.

The main aim of this study is to collect and analyse the forced outage failures data for a period of at least five

OVERHEAD LINES	POSITIVE SEQUENCE CHARACTERISTICS						ZERO SEQUENCE CHARACTERISTICS			
	R_1/K_m		X_1/K_m		B_1/K_m		R_o/K_m		X_o/K_m	
	Ohm	p.u	ohm	p.u	ohm $x10^{-6}$	p.u $x10^{-6}$	ohm	p.u	ohm	p.u
REDWING	0.095	0.00064	0.41	0.00234	2.78	485	0.328	0.00188	1.10	0.00625
TEAL	0.105	0.0006	0.388	0.00221	2.94	514	0.338	0.00194	1.05	0.0060
LARK	0.16	0.00031	0.402	0.00228	2.86	500	0.393	0.00224	1.09	0.0062
ORIOLE	0.19	0.00108	0.425	0.00243	2.81	490	0.425	0.00243	1.15	0.00655
PARTRIDGE	0.239	0.00136	0.415	0.00237	2.75	480	0.472	0.0027	1.12	0.0064
COPPER	0.173	0.00078	0.48	0.00275	2.8	488	0.372	0.00213	0.19	0.0068

TECHNICAL SPECIFICATION OF 132 KV. OVERHEAD LINES FOR

N. E. A. GRID

Table(4.1)

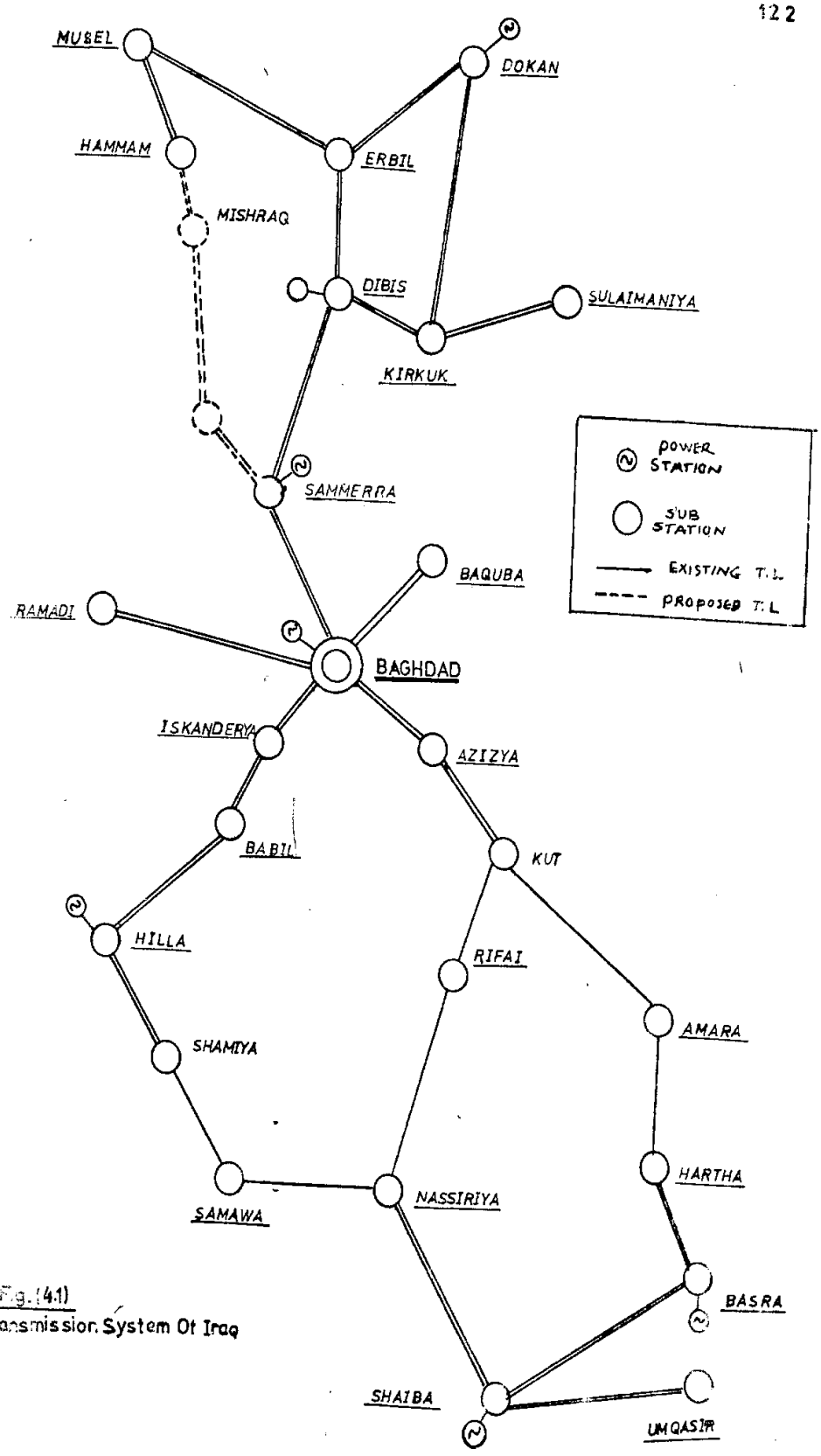


Fig.(4.1)
132 K.V. Transmission System Of Iraq

years in order to obtain the reliability indices for the line and equipments of, the transmission system in Iraq. Later, it is found that the reports of failure occurrence on line and equipment for the pre 1969 periods were very poorly sorted out. The available reports for the pre-1969 periods are so few and confined that it is impractical to be examined in any scientific research. Therefore, the objective is settled to cover failures for the 1969-1973 period only.

The forced outage failures data are obtained by checking out all the available files individually in the dispatching centre. These files are just meant to keep the papers which are supposed to take their way to the head of operation department in the computer center of the N.E.A. There is no particular way to file these reports properly as to facilitate their usage for research and one should read all the papers to get the relevent information.

4.3.1 Failures Data

The information presented here in are taken from the daily trouble reports published by the above mentioned centre.

Table (4.2) presents the resulting statistical studies for the number, duration and causes of permanent outages during both stormy and normal weather for the 132 K.V. transmission and tie lines in Iraq. The rates are pres ented over a 5-years period.

Table(4.3) gives the statistical results for number,duration and causes of permanent outages for the 132 K.V. Substation facilities in Iraq for the five years period of study.

Tables(4.4 A,B,C) gives the average number per month per year of occurrence of temporary outages for the transmission and tie lines in the main three regions of Iraq respectively.

Table (4.5) presents a sample table for the temporary outage statistical data for the transmission lines.

4.2.2 Failure Types and Modes

Excluding outages due to over load and maintenance, the forced outage failures in Iraq are classified into two major groups, namely, persisting or permanent forced outage, and the temporary failures. The term permanent outage indicates that the faulty component in a power system must be repaired before it can be restored to service with a definite repairing time.

TABLE (4.2) :

STATICAL TABLE OF PERMANENT OUTAGES FOR 132.KV. TRANSMISSION LINES IN IRAQ

LENGTH OF LINE (KM)	TYPE OF LINE	PERMANENT OUTAGE DURING NORMAL. W		PERMANENT OUTAGE DURING STORMY. W		CAUSE OF FAILURE					
		FAILURE.No.	DURATION H : Min	FAILURE.No.	DURATION H : Min	INSULATOR BREAK DUWN	WEATHER CONDITION	POLLUTION OF INSUL.	TOWER FAILURE	MECH. INJURIES	OTHER * CAUSES
22.0	Cu	1	12:00	1	03:20		Fog & Humidity	X			X
22.0	Cu										
23.0	Cu	1	6:00					X			
23.0	Cu	1	6:00					X			
36.0	Cu			1	05:45		HUMID WEATHER	X			
36.0	Cu			1	05:45		HUMID WEATHER	X			
51.0	Cu										
51.0	Cu										
142.0	O	1	13:55	1	06:00		RAIN & STORM	X Due To brick Factories			X
171.0	L	4	1:15 5:00	2	00:17		FOG & Thn. HUM.	XXX		X	X X
17.0	L	1	1:20	2	00:16		FOG & Thn. HUM.	X X			X
80.0	O										
189.0	O	1	00:05								X
96.0	O										
101.0	P	1	00:05					X			
70.8	P	2	01:00	1	10:00		STORM				X X
86.0	P	2	17:15								X X
86.0	P	1	5:15								X
82.0	P										
82.0	P										
94.0	L	2	24:15							X	X
94.3	L	1	06:50			X					
23.0	T										
14.3	T	1	00:05			X					
14.0	T										
14.2	T	2	00:05			X				X	

CONT. SHEET- 2

	LENGTH OF LINE (KM.)	TYPE OF LINE	PERMANENT OUTAGE DURING NORMAL W		PERMANENT OUTAGE DURING STORMY W		CAUSE OF FAILURE					
			FAILURE No.	DURATION H : Min	FAILURE No.	DURATION H : Min	INSULATOR BREAK DOWN	WEATHER CONDITION	POLLUTION OF INSUL.	TOWER FAILURE	MECH. INJURIES	OTHER CAUSES
	104.7	P	2	43 : 40	1	10 : 25	X	WIND STORM		X	X	
	104.7	P	4	79 : 25	1	10 : 25	XX	STORM, WIND		X	X	X Malope ration
	23.0	T	2	22 : 62			XX					
	17.5	T										
	38.2	L	4	1 : 20					X		X	XX(SURGE)
	38.2	L	2	0 : 30								X X
	14.2	L										
2	14.2	L										
	12.5	T			1	00.03		WIND, RAIN				
	15.4	T	1	13 : 29								X
	52.3	P	1	00 : 15	1	17 : 00		WIND, STORM		X	X	
	52.3	P	2	14 : 00	1	17 : 00		WIND, STORM		X	X	X
1	6.9	L										
2	6.9	L										
	177.0	R	3	9 : 40			X				X	X {Mal- operatio
	177.0	R	2	0 : 30			X					X
	102.1	P	9	29 : 55			X		X		X X	XXXXX
	102.1	P	11	55 : 53			XX	RAIN (X)				XXXXX XXX
	57.5	O	2	22 : 00	2	1 : 00	X	CLOUD				XXX
	57.5	O	3	11 : 00			X				X	X
	94.2	L	4	90 : 28			XX				X	X
	94.2	L	5	78 : 03			XXX				X	X
	18.5	P										
	18.5	P										
	41.0	P										
	41.0	P										

	LENGTH OF LINE (KM)	TYPE OF LINE	PERMANENT OUTAGE DURING NORMAL. W		PERMANENT OUTAGE DURING STORMY. W		CAUSE OF FAILURE				
			FAILURE. No.	DURATION H : Min	FAILURE. No.	DURATION H : Min	INSULATOR BREAK DOWN	WEATHER CONDITION	POLLUTION OF INSUL.	TOWER FAILURE	MECH. INJURIES
DI 1	104.7	P	2	43 : 40	1	10 : 25	X	WIND STORM		X	X
DI 2	104.7	P	4	79 : 25	1	10 : 25	XX	STORM, WIND		X	X
ALI	23.0	T	2	22 : 62			XX				
IYA	17.5	T									
RRA 1	38.2	L	4	1 : 20					X		X
RRA 2	38.2	L	2	0 : 30							
IBA 1	14.2	L									
AIBA 2	14.2	L									
ZALI	12.5	T			1	00.03		WIND, RAIN			
ZIRIYA	15.4	T	1	13 : 29							
UBA 1	52.3	P	1	00 : 15	1	17 : 00		WIND, STORM		X	X
UBA 2	52.3	P	2	14 : 00	1	17 : 00		WIND, STORM		X	X
AGHD. 1	6.9	L									
AGHD. 2	6.9	L									
IS 1	177.0	R	3	9 : 40			X				X
IS 2	177.0	R	2	0 : 30			X				
NYA 1	102.1	P	9	29 : 55			X		X		X X
NYA 2	102.1	P	11	55 : 53			XX	RAIN (X)			
1	57.5	O	2	22 : 00	2	1 : 00	X	CLOUD			
2	57.5	O	3	11 : 00			X				X
1	94.2	L	4	90 : 28			XX				X
L 2	94.2	L	5	78 : 03			XXX				X
AM 1	18.5	P									
MAM 2	18.5	P									
5 1	41.0	P									
5 2	41.0	P									

FOR NUMBER, DURATION AND CAUSES OF
PERMANENT OUTAGES FOR 132.K.V. SUBSTATIONS
IN IRAQ
PERIOD JAN.1971 — DECEMBER.1973

ON	FAULT ON TRANSFOMERS TR.1		TR.2		WEATHER CONDITION	CAUSES OF FAILURE	FAULTS ON C.B's		FAULTS ON ISOLATOR		FAULTS ON BUS -BARS & COUPLE	
	NUMBER	DURAT.	NUMBER	DURAT.			NUMBER	DURATION	NUMBER	DURATION	NUMBER	DURATIO
:	2	25 H	7	8.0 H	NORMAL 8 STORMY 1	O/C RELAY & MECH. INJURIES						
.	1	24.0 H	1	18.0 H	NORMAL	HYDROLIC SYSTEM & OIL-LEAKAGE						
AJAF	1	6.5 H			NORMAL	V.T BURNT					1	3.0 H
A	1	2.0 H			NORMAL							
	1	5.0 H	1	7.0 H	NORMAL							
					NORMAL	CABLE END-BOX	1	6.0 H				
	1	3.0 H			NORMAL		1	9.0 H			1	2.5 H
			4	36.0 H	NORMAL 3 STORMY 1	V.T & C.T BURNT					1	5.2 H
.D	2	3.0	2	9.0 H	NORMAL	HEAT & TAP CHANGER					3	13.0 H
L	1	0.1 H	4	23.2 H	NORMAL	SHUNT REACTOR	2	12.0H			1	2.0 H
	1	2.0	1	1.45 H	NORMAL	LIVE CREATURS						
	1	1.5 H	1	0.1 H	NORMAL	BOCHHOLS RELAY						
	1	4.0	1	2.0	NORMAL	LIGHTNING ERRESTORS						
MAM	1	6.0	1	2.3	NORMAL	V.T BURNT INSULATION PROB	1	4.0 H				
			1	10.0 Min	HUMIDITY DUNSE FOG		1	3.0 H				
					NORMAL		1	2.5 H				
AIBA			1	0.35 H	STORMY	RAIN & STORM C.B BUSHING	1	3.25 H			1	7.0 H

Table (4.4 A) : 5-Year Statistical Table for The Number of Temparary outages occurrence on 132.K.V Transmission Lines In The Northen Region of Iraq

YEAR	NUMBER OF TEMPORARY OUTAGES PER MONTHES OF THE YEAR												TOTAL OUTAGES PER ONE YEAR
	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	
1969	0	6	5	3	1	5	3	1	2	1	2	4	33
1970	1	2	4	0	3	3	1	1	0	0	0	1	16
1971	0	5	3	6	12	10	0	0	0	0	1	3	40
1972	3	1	24	14	10	1	1	4	2	2	1	4	67
1973	0	2	3	13	1	1	2	0	0	0	1	1	24
MEAN PER MONTH	0.8	3.2	7.6	7.2	5.4	4.0	1.4	1.2	0.8	0.7	1.0	2.6	-

Table (4.4B) : 5-Years Statistical Table for The Number of Temporary outages occurrence on 132.K.V Transmission Lines In The Central Region Of Iraq.

YEAR	NUMBER OF TEMPORARY OUTAGE PER MONTHES OF THE YEAR												TOTAL OUTAGES PER ONE YEAR
	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.	
1969	0	0	2	2	2	0	0	2	1	1	4	0	14
1970	0	0	0	1	0	0	0	0	1	1	1	1	5
1971	3	3	0	1	9	1	2	1	3	3	2	3	31
1972	4	3	6	8	6	0	8	3	10	4	6	6	64
1973	4	5	5	3	7	2	1	4	7	0	1	7	46
MEAN PER MONTH	2.2	2.2	2.7	3	4.8	0.6	2.2	2.0	4.4	2.25	2.12	4.6	--

Table (4.4 C) : 5-Years Statistical Table for The Number of Temorary Outages Occurrence on 132.K.V Transmission Lines In The Southern Region of Iraq.

YEAR	NUMBER OF TEMPORARY OUTAGES PER MONTHES OF THE YEAR												TOTAL OUTAGES PER ONE YEAR
	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	
1969	7	2	4	0	1	0	0	0	0	0	0	0	14
1970	3	0	0	3	2	1	1	1	0	3	4	2	20
1971	0	0	3	1	2	0	0	1	2	2	2	1	14
1972	4	2	3	7	1	1	0	0	7	0	3	1	29
1973	4	2	1	1	2	0	1	0	1	3	7	2	24
MEAN PER MONTH	3.6	1.2	2.2	2.4	1.6	0.4	0.4	0.4	1.6	1.25	3.2	1.4	-

Table(4.5): Sample Statistical Table for Temporary outages on 132.K.V.T.L

(Year 1972)

132.K.V. TRANSMISSION LINES	NUMBER OF TEMPORARY OUTAGES PER MONTH											
	JAN.	FEB.	MAR.	A.R.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
SHUAIBA-ABUFLUS 2	1											
DUARA-KADHIMIYA				1	1							
HASSIRYA-SHUAIBA1	1		1									
DIBIS-ERBIL 1	2		1		1							
DIBIS-ERBIL 2	2											
KIRKUK-SULAIMA.1	2		9	8	3		1	3	1	1		
KIRKUK-SULAIMA.2	1	1	15	5	7	1		1	1	1	1	
N.BAGHDAD-KUT 1&2		1			1			2	1		1	1
KUT-RIFAI	2	2	2									
N.BAGHDAD-GHAZALI			2	1							1	1
N.BAGHDAD-BAQUBA2	1			1			1					
SAMERRA-TAJI			1				1					

A temporary outage which is, by definition, selfclearing action, so that a faulty component can be restored to service by reclosing action that may be done either manually or automaticaly.

The causes of failures that leads to either of these two types of outages as investigated from the trouble and failure reports are as follows:

4.2.2.1 Non-Meteorological Causes

Many causes arises by live creatures such as birds, snaks and cats. Birds that stand on or fly by the lines their wings will shorten the distance of insulation between the two live lines, such that a short circuit will be formed. There are two possibilities in this case; either the bird will die and fall to the ground, and this causes a temporary failure in the system or it dies and remains on the transmission line causing a permanent outage of the line itself.

Snaks and cats cause a lot of problems in the major stations and substations which may lead to severe outages for the transmission system.

The insulator pollusion is a major problem in this country. The lines that are crossing the villages near the brick factories and that crossing the salty regions suffer a

problem of contamination of dust and salt on its string of insulators . This causes either permanent or temporary failures especially when the weather being highly humid during winter and autumn.

In regard to another causes, the problem of insulator breakdown due to mechanical actions is also a major problem in this country. The small solid particles of the sand containment are normally carried out by the strong wind storms. These heavy particles strike the insulators and lead to break down problems.

There are many other causes, which are either known or unknown, that cannot be classified or investigated. These types of problems may cause a permanent or temporary outages and are given in the statistical tables.

4.2.2.2 Meteorological Problems.

In the comprehensive statistical study, that is made on the daily reports of troubles and problems which are causing the forced outage failures on the transmission system, it is noticed that the fluctuating environment in, Iraq has agreat effect on the system and component failures, especially on that part which is exposed to the weather conditions.

The meteorological phenomena such as the thunder storms, rainfall, relative humidity, dust storms, snow fall and any other phenomena affect the failure rate of lines and equipments. Therefore statistics, for several parts of Iraq are compiled to give any meteorological phenomena that might cause any failure problems.

The Meteoreolgical Department in Baghdad is requested to supply all information about the weather conditions and data from all major meteorological stations for the period of study. These stations are listed below according to their location in the country :

- Mousel
- Kirkuk
- Khanagin
- Rutbah
- Habbaniya
- Baghdad
- Hai
- Diwaniya
- Nassiriya
- Basrah

Appendices (B1, B2, B3, B4, B6, B7)give the average expected number of occurrence of the various meteorological phenomena in this country.

Figures (4.2, 4.3, 4.4) shows the montly distribution of the average number of occurrence of thunder storm,dust storms and relative humidity over the period of study respectively.

4.2.3 Correlations Between the Temporary outages and Meteorelogical Phenomena.

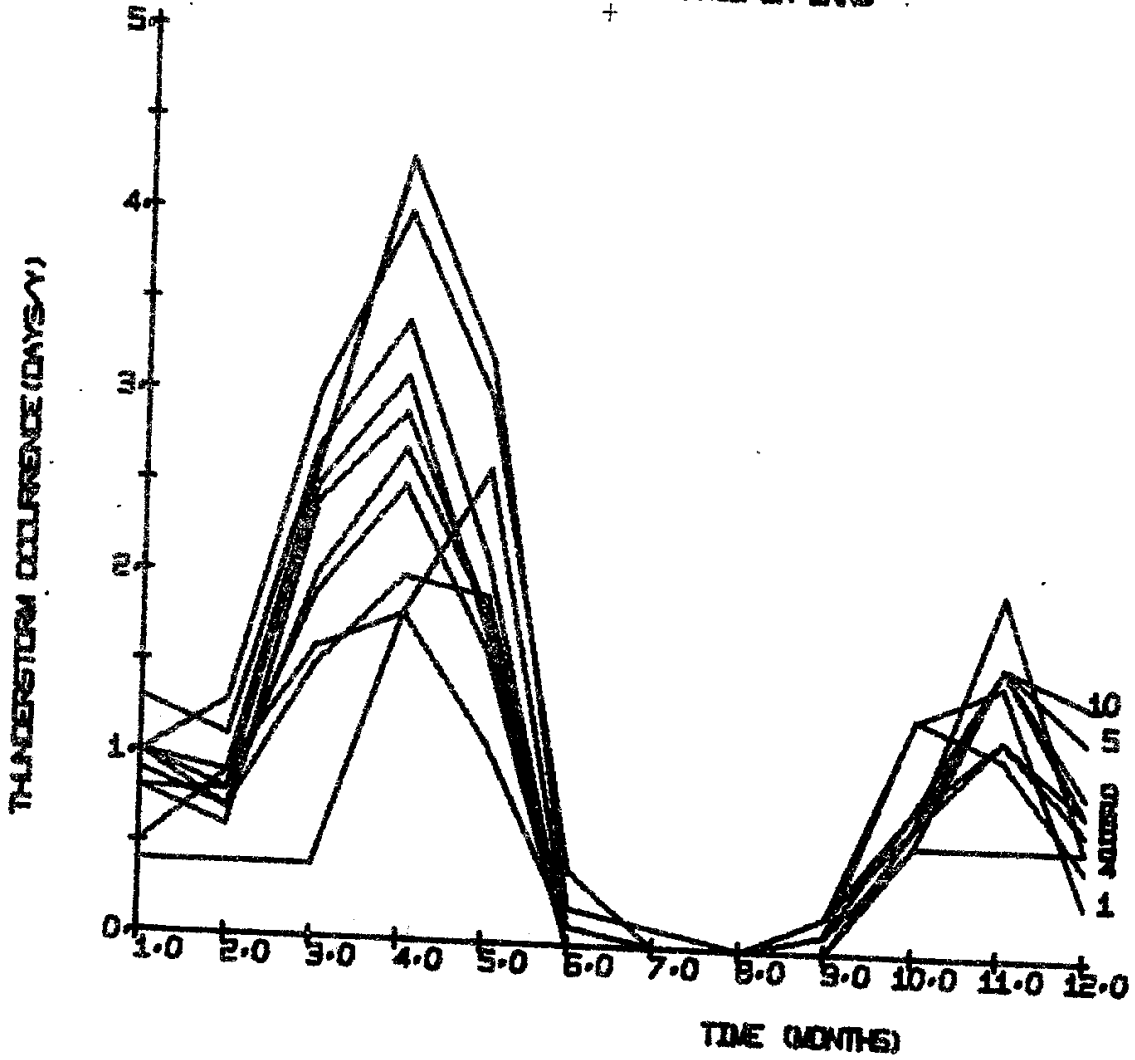
It is found from previous study, that the temperary outages are the most common failures that occurs on Iraqi transmission system. The main factors that cause this type of outage as given in the trouble reports, are the meteorological phenomena, insulator pollusion and any other causes. A great amount of attention is focused in this thesis to study the relations between the temporary outages and the different meteorological phenomena and to find a numerical relation-ships for this study.

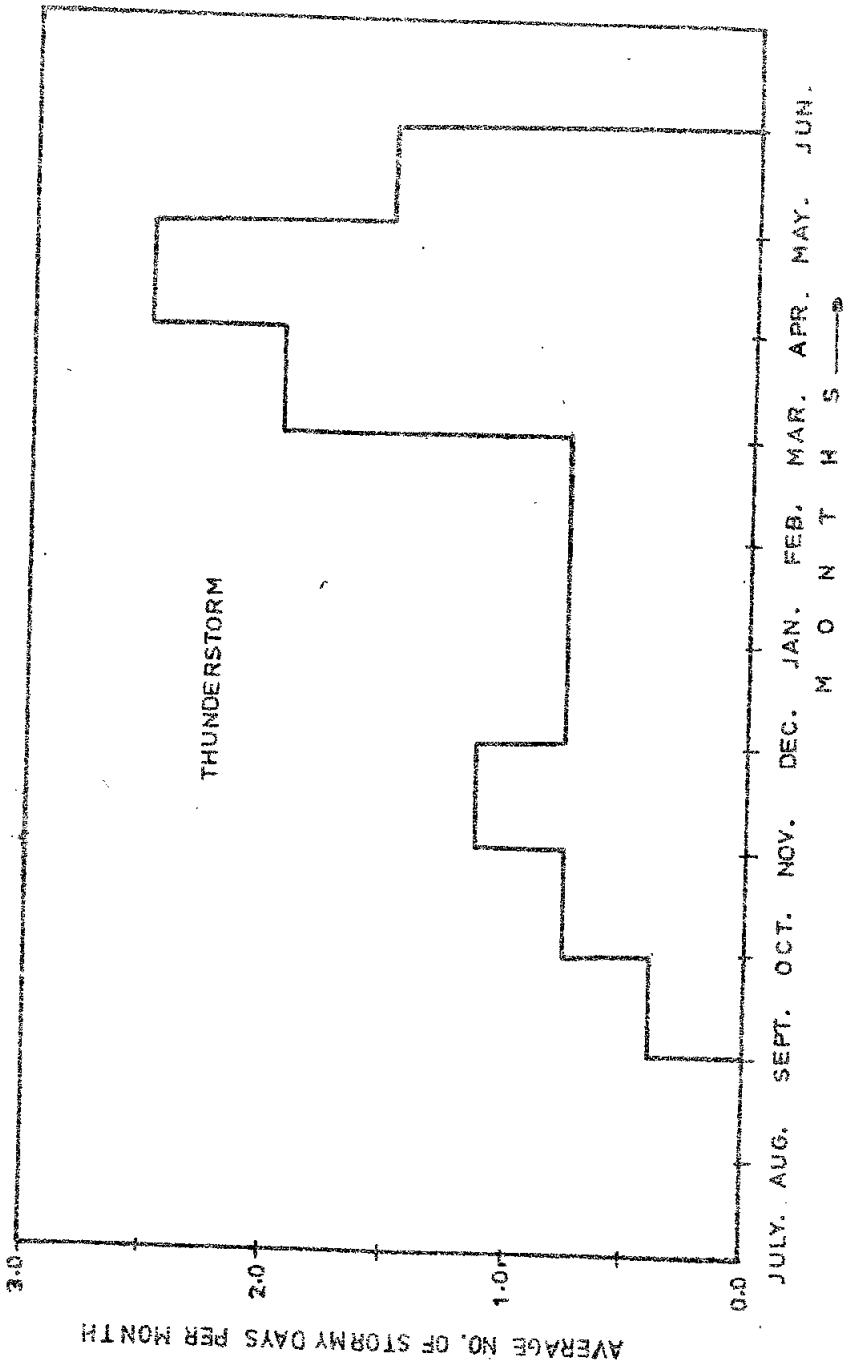
4.2.3.1 Temporary Outage Distribution

The distribution of the average number of temporary outage over the months of the year is shown in fig. (4.5) for the three regions of Iraq.

The peak period for the northen region is during Febreuary and march. It is also noticed that the central

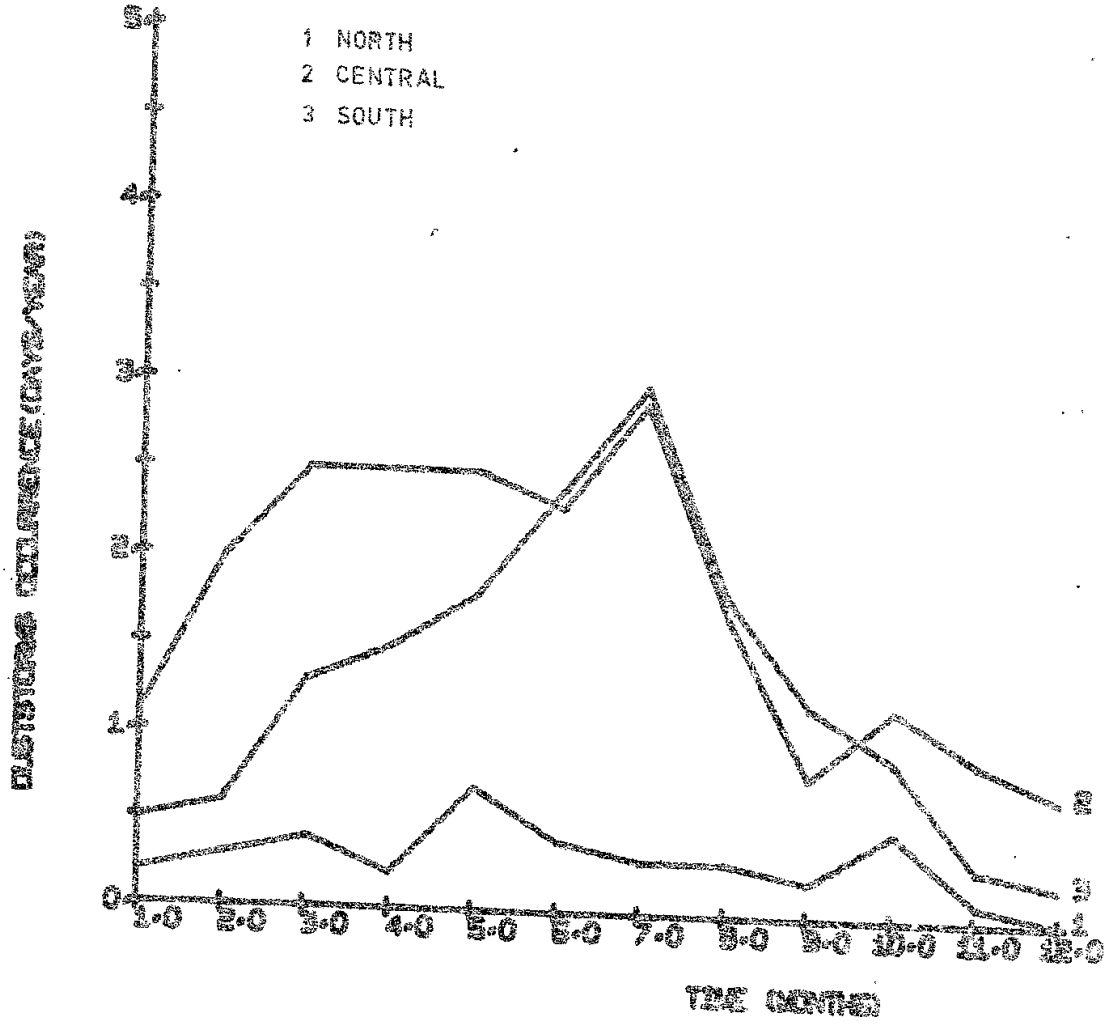
FIG. (4.2a) THUNDERSTORM OCCURANCE IN IRAQ

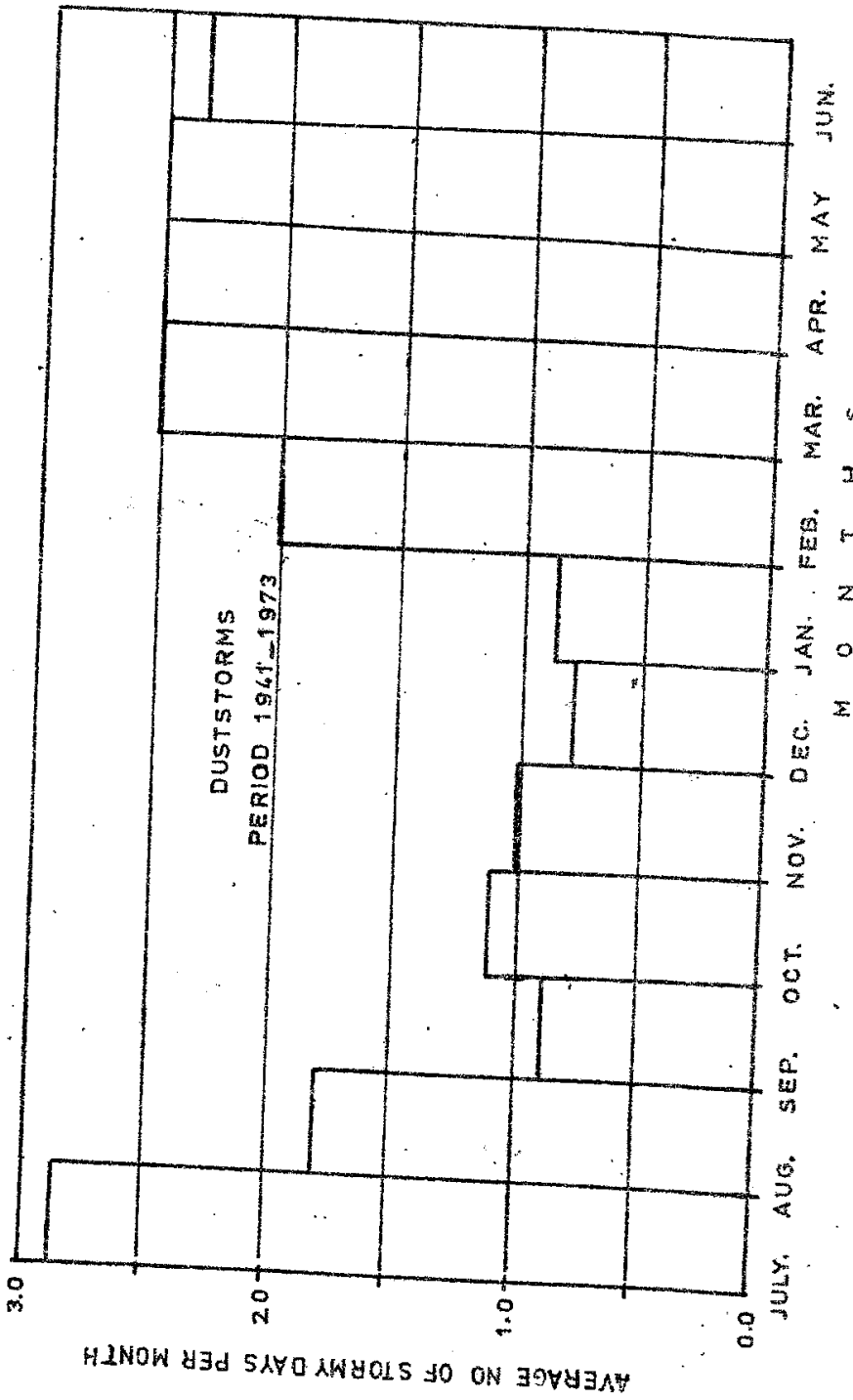




FIG(4.2b) : AVERAGE NUMBER OF DAYS PER MONTH OF THUNDERSTORMS OCCURRENCE IN BAGHDAD PERIOD 1941 – 1973

FIG. (4.3a) DUST STORMS





FIG(4.3b) : AVERAGE NUMBER OF DAYS PER MONTH OF DUSTSTORM OCCURRENCE IN THE CENTRAL REGION

FIG (4.4) RELATIVE HUMIDITY.

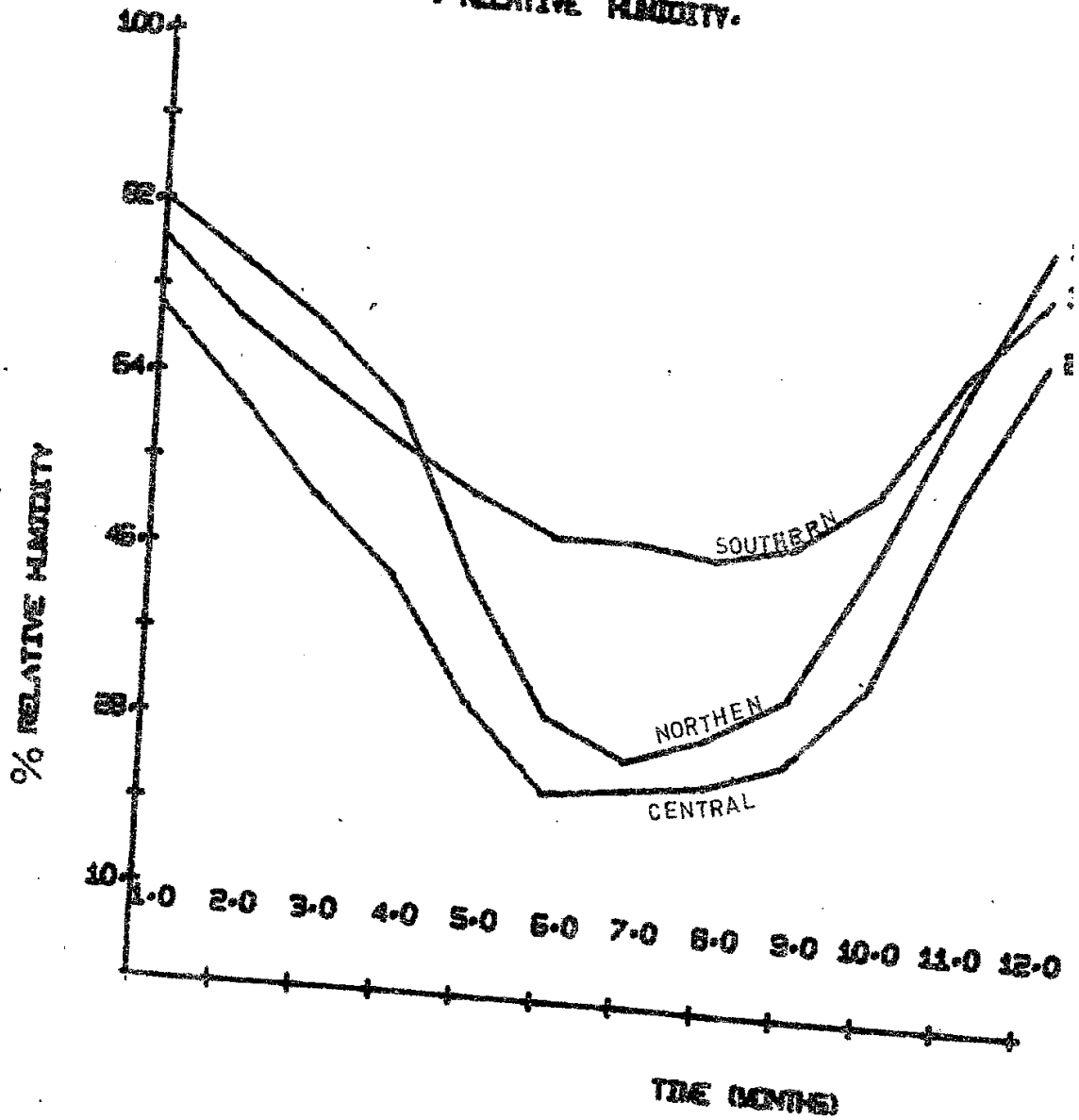
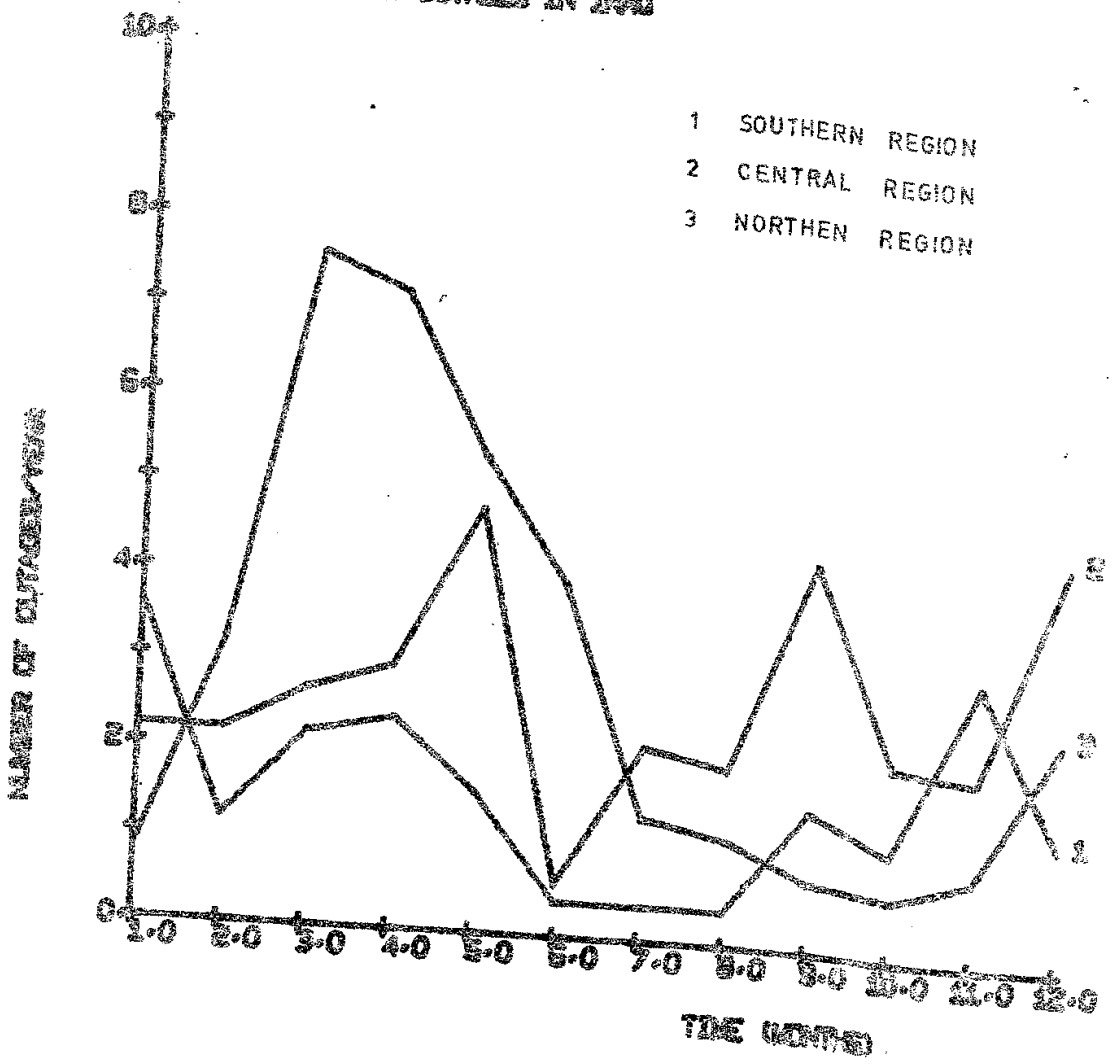


FIG.[4.5 -1 :

TEMPORARY OUTAGES IN 2040

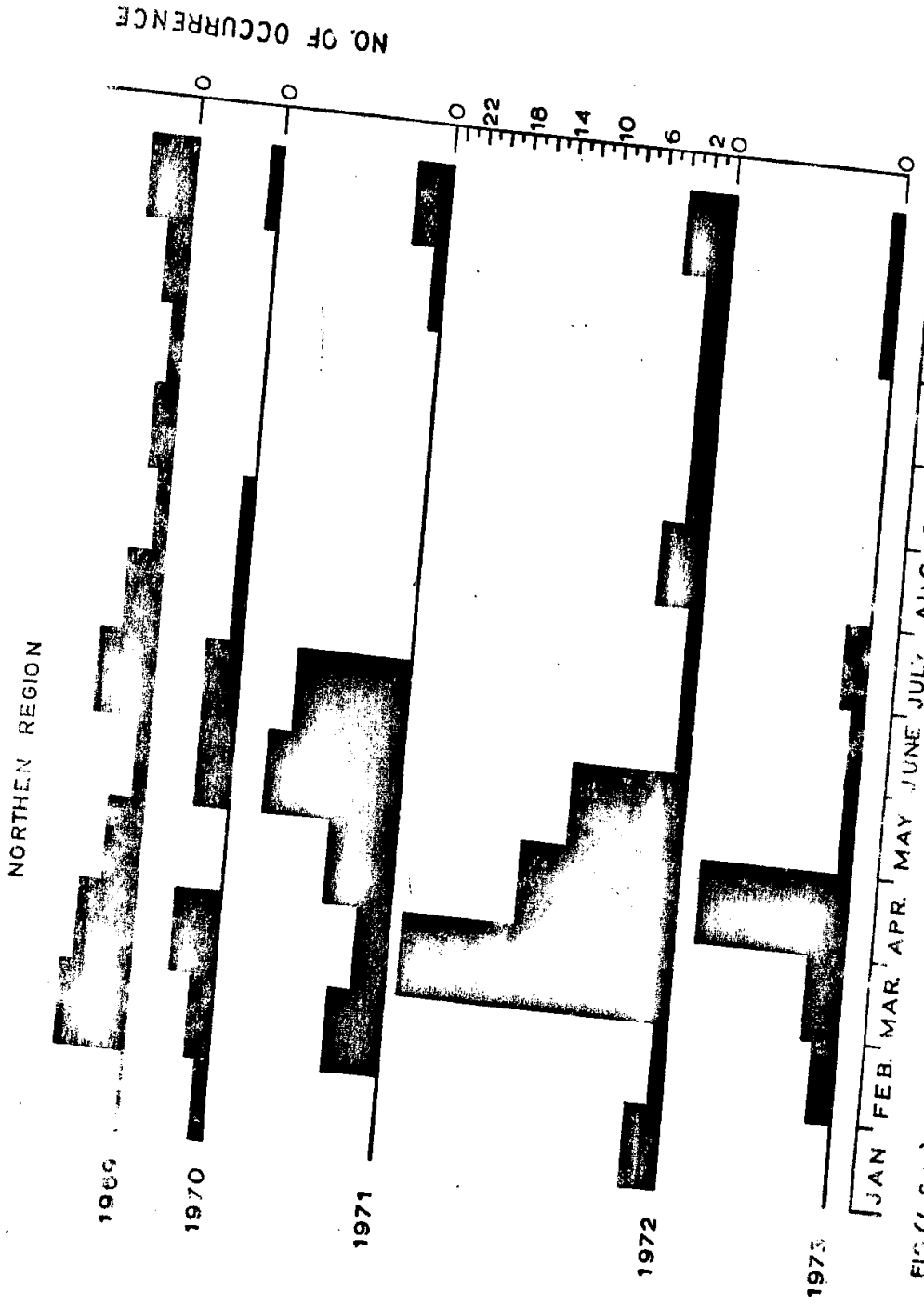


region has two peaks, one occurs at the period April-May, and the other occurs during August-September. The Southern region has a peak period during March-April. Generally it can be said that failures occurrence is concentrated during the period (February-June) for the three regions of Iraq.

Fig.(4.6-8) shows the monthly failure distribution for the individual five years of study and the over all period for the three regions. The over all distribution marks two distinctive peaks in failures occurrence, namely in April and August. The graph also shows an increase in failures during the winter and spring months Feb-May, as well as over August. If these findings are related to the meteorological phenomena variations which are shown in figs.(4.2,4.3,4.4), one can say that there are good relationships between these two random events. An attempt is made to examine the degree of correlation between these temporary failures and meteorological phenomina in the three regions of Iraq, and correlation-factors are obtained over the period of study.

The correlation factor is given by the following formula(21)

$$r = \frac{n \Sigma xy - \Sigma x \Sigma y}{\sqrt{[n \Sigma x^2 - (\Sigma x)^2 \quad [n \Sigma y^2 - (\Sigma y)^2]}} \qquad \ldots(4.1)$$



NORTHERN REGION

FIG.(4.6 a): MONTHLY TEMPORARY OUTAGE DISTRIBUTION OVER FIVE YEARS FOR THE NORTHERN REGION

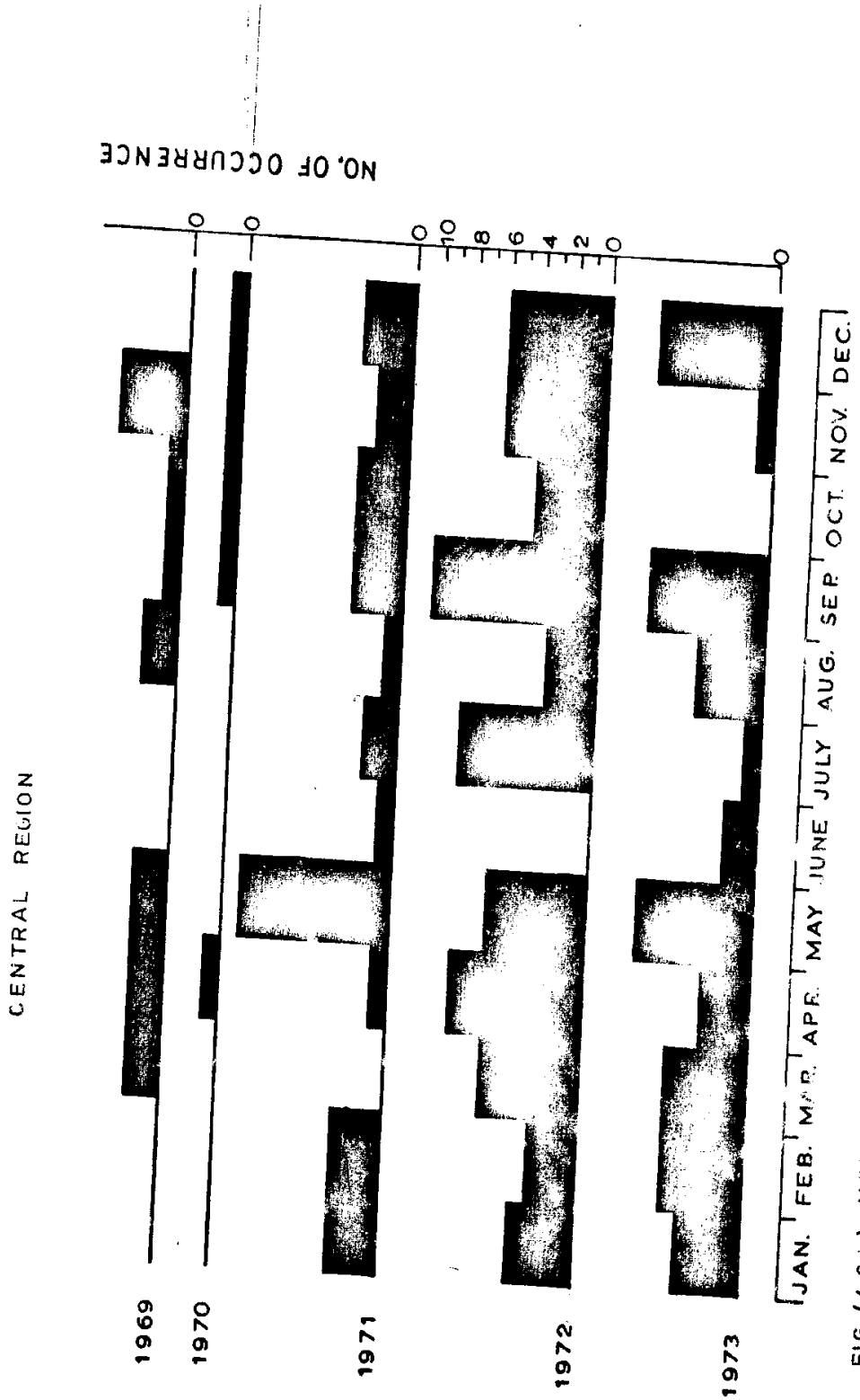


FIG.(4.6 b): MONTHLY DISTRIBUTION OF THE TEMPORARY OUTAGES OVER FIVE YEARS FOR THE CENTRAL REGION

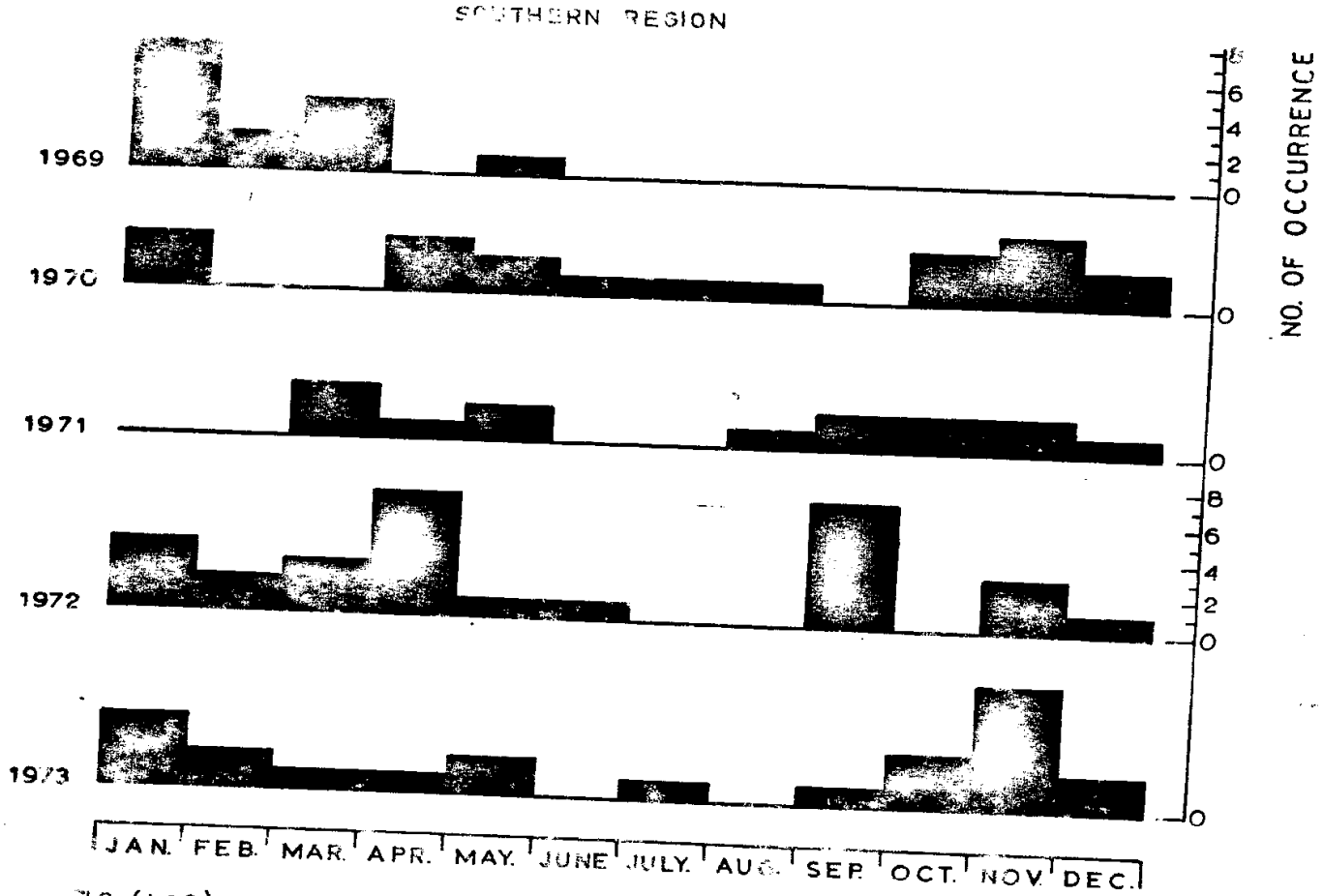


FIG. (4.6C) : MONTHLY DISTRIBUTION OF THE TEMPORARY OUTAGES OVER FIVE YEARS FOR THE SOUTHERN REGION

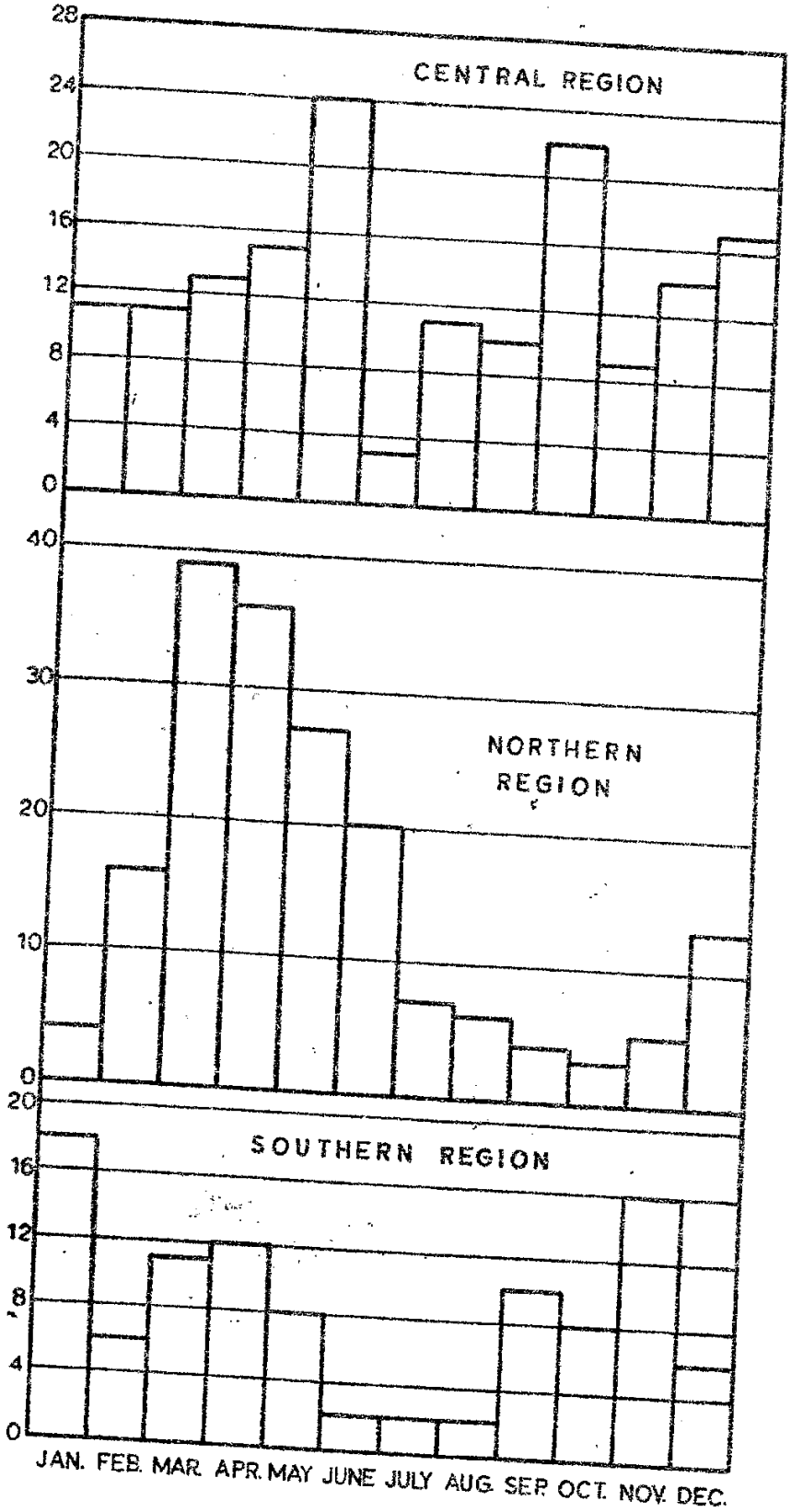


FIG (4.3) : MONTHLY

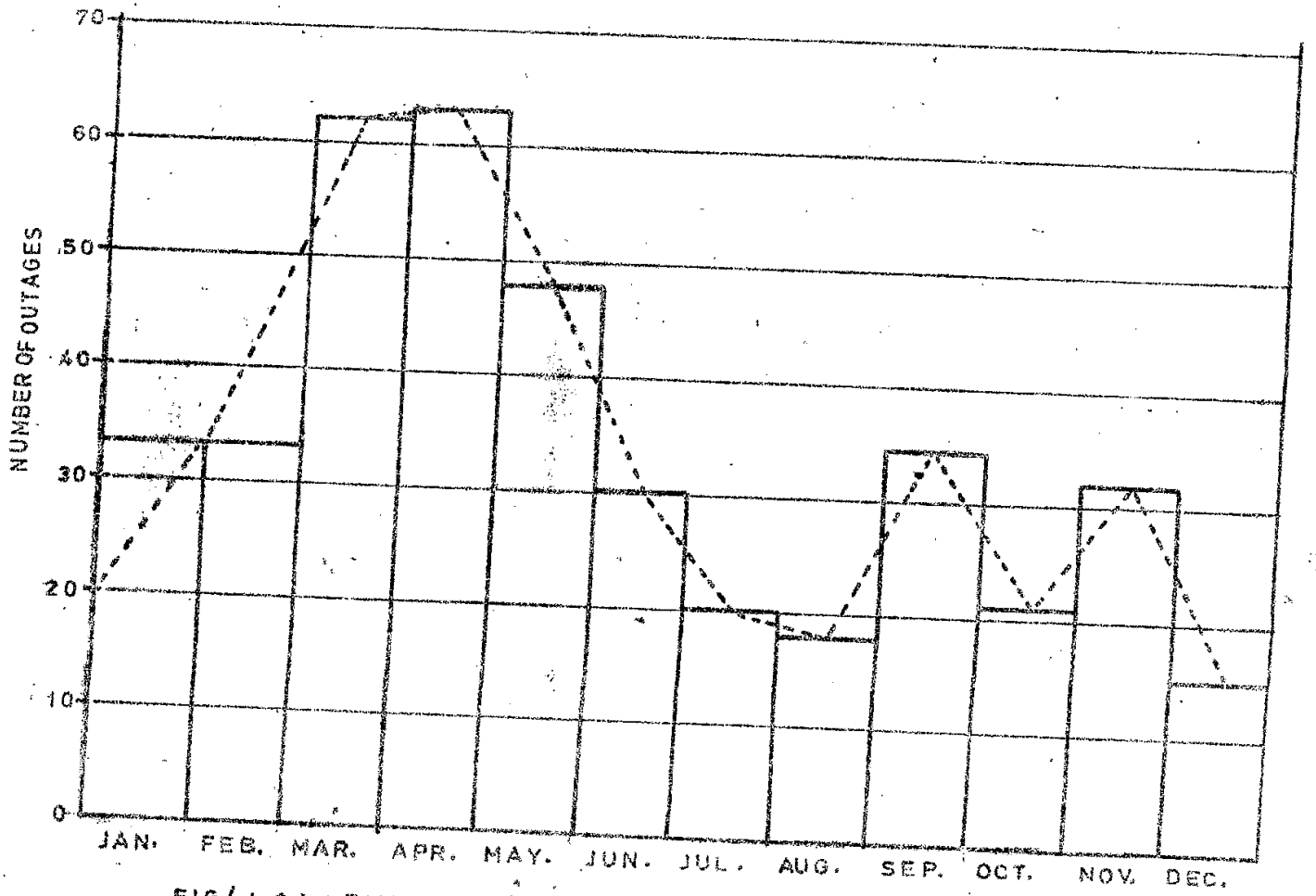


FIG.(4.8) : DISTRIBUTION OF TEMPORARY OUTAGES IN IRAQ DURING 5_YEARS (1969_73)

where x,y are the independent and dependent variables respectively and n = no. of pairs of the two variables.

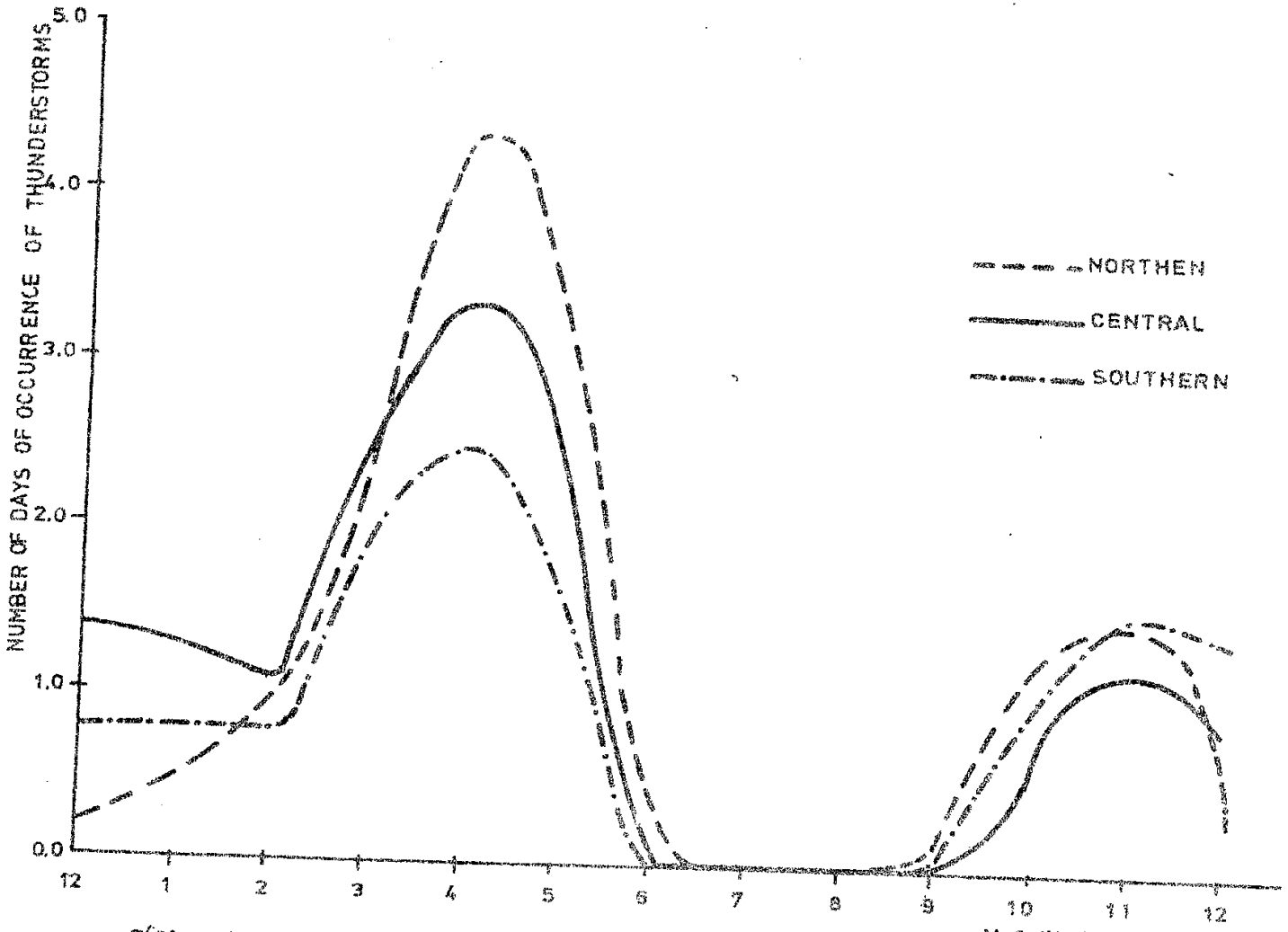
The computer programme List of the correlation factor calculation is given in appendix (B8)

4.2.3.2 Temporary Outage-Thunder Storms Correlation

The average number of occurrence of thunder storms for the three regions of Iraq is shown in fig(4.9). It is noticed that the maximum average number of expected occurrence of this phenomena in the three regions occurs during the period March-June. If this is related to the variation of temporary outage for the same three regions given in fig.(4.5), It is seem that the increase in failures are quite Justifiable. The February-March peak, being the greatest, can be due to the unfavourable climatic conditions during this period and the marked increase in thunderstorms period. The result of the correlation test is given in table (4.6) as follows .

Table 4.6

Region	Correlation Factor %
Northen	79.7
Central	32.0
Southern	62.7



FIG[4.9]: AVERAGE NUMBER OF OCCURRENCE OF THUNDERSTORMS PER MONTH IN IRAQ PERIOD 1941_1973

It is noticed that this meteorological phenomena has a great effect on this type of outage in this country especially at the northen and southern regions.

4.2.3.3 Temporary outage-Relative humidity Correlations

Referring to fig (4.4) which shows the average monthly variations of relative humidity for the three regions of Iraq, it is observed that the southern region is the most highly humid as compared with the other two regions.

The distribution of this phenomena shows that the relative humidity curve has one peak and one vally; the peak for the three regions occurs during January while the vally ocurs during July. As a matter of interest, the distribution of the relative humidity data is seen to be normally distributed. The peak ocurs during January and this decreases for the other months of the year. Table(4.7) gives the result of the correlation test between this phenomena and the temporary outage.

Table (4.7)

REGION	CORRELATION FACTOR %
NORTHEN	18.00
CENTRAL	15.70
SOUTHERN	65.58

It is seen that the southern region is the only region which is greatly affected by the variation of relative humidity. Statistically speaking there is a relations . between the temporary outages and humidity in this region.

4.2.3.4 Temporary Outage-Dust Storm Correlations

The average variation of dust storms vis-1000 meter or less in different regions of Iraq is shown in fig.(4.3). It is noticed that the distribution of this variation in approximately normal with the peak occurring during July.

The heaviest duststorm period in which the maximum expected average number of occurrence of dust storms is during June-July-August. It is also noticed from these figures that the southern region is the most dusty region compared with the other two regions. Table (4.8) gives the correlation between the temporary outage failures and the dust storms in the three regions of Iraq as tested by the statistical methods.

Table (4.8)

REGION	CORRELATION FACTOR %
NORTHEN	23.7
CENTRAL	33.6
SOUTHERN	52.7

From the statistical point of view, it is found from the above table that this phenomena causing a temporary outages with low correlation factor for the two northen and central regions and moderate one for the southern region.

If the data of dust storms are shifted by three month period. It is seen that correlation between dust storms and the temporary outages will increase. It is found that with three month time delay, there is a higher correlation between the two events; the following table gives the tested results.

Table (4.9)

REGION	CORRELATION FACTOR %
NORTHEN	.....
CENTRAL	79.8
SOUTHERN	62.0

It is obvious from this delaying process that the dust-storms which happens frequently in summer periods has a great effect on the insulator pollusion due to dust and salt contaminations,

4.2.3.5 Snow Effects

Although the hail and fog have little effect on the temporary outage, the snow fall in the northen region

has a great effect on this type of failure, the correlation factor for the winter period only is estimated for this study and it was about (63.2) percent.

4.3 Calculation of Measures of Reliability For Iraqi Transmission Systems

In calculating the reliability measures of any given system, two basic principles are applied.

a. A mathematical model for the calculation of various measures of reliability in the system must be developed.
b. Comparing the resulted data with previous standard figures.

The mathematical model is developed in this thesis in a form of a mathematical equations which are implemented in a segments of a computer programmes.

There are no previous studies or any statistical study done before on this subject on the Iraqi system. Therefore there are no experience or previous standard data at all. However, engineering sense may be encountered, through the develope of this work.

In the section to follow, the method of calculation of various measures of reliability for Iraq are given as far as the effect of fluctuating environment on these measures are concerned.

4.3.1 Fluctuating Environment Effects[13]

Excluding design, the failure due to environment fluctuation for that part of a power system which is exposed to the weather is one of the main problems of transmission systems.

In general the weather state can be considered as being in two conditions, either normal or severe states. This consideration of 2-State fluctuating environment leads to two definition of failure rate for any equipment or line in a power system.

Fig.(4.10) illustrate an environment which fluctuate between normal and severe states as a random process.

If during severe weather a number of components making a system hit by lightning or heavy storms simultanously i.e common event action; several component failures may occur during short period of time. This bunching of failures have a great effect on system reliability.

In view of the above discussions and definitions Iraqi climate is considered as a 2-state fluctuating environment for reliability analysis. Table (4.10) gives the storm definitions in Iraqi area.

The degree of completness in representing the effect of fluctuating environment in transmission system reliability calculation is limited largly by the available data. Field trouble reports of weather is a contributing agent in the

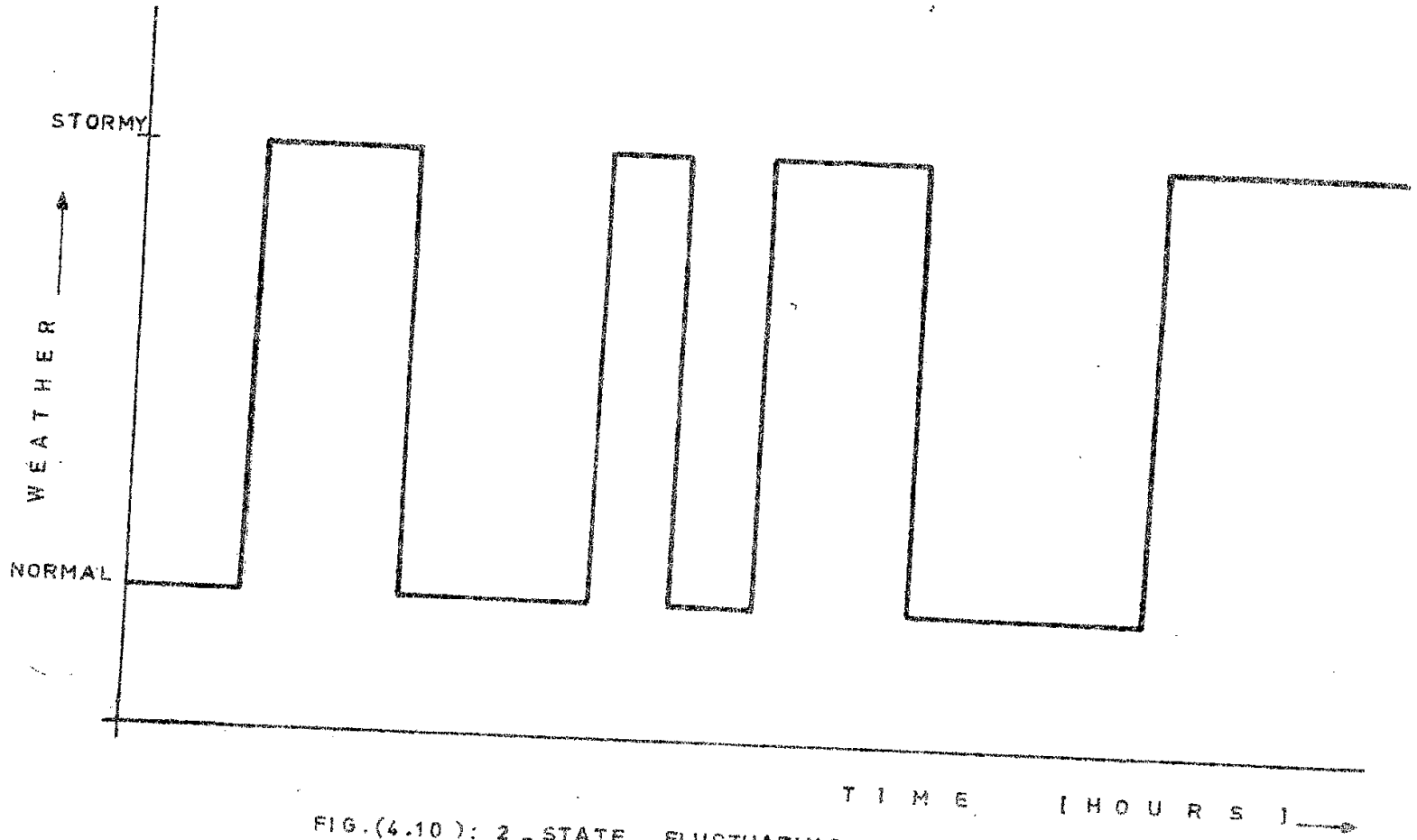


FIG.(4.10): 2_STATE FLUCTUATING ENVIRONMENT REPRESENTATION

Table 4.10

STORM DEFINITIONS IN IRAQ

Weather Condition	Minimum Wind Velocity (Knots)	Minimum Duration HOURS	Minimum Temp. F.
Thunder Storm	- - -	- - -	- - -
Heavy Thunder Storm	- - -	- - -	- - -
Tornado	- - -	- - -	- - -
Squall	- - -	- - -	- - -
Moderate Rain	20	5	- - -
Heavy Rain	20	- - -	- - -
Dusty Wind	20	- - -	- - -
Wind only	25	- - -	- - -
Moderate Snow	- - -	- - -	28
Heavy Snow	- - -	- - -	28

Component failure can readily be seperated into " normal weather " and " storm associated " failures.

As it is seen before these trouble reports also give a broad indication as to the type of failure-causing weather, such as lightning, wind or storms. This makes it possible to classify failures according to type of storm. Given these data, together with statistics on the number of components in service and the average time each year during which the various kinds of weather prevail, average component failure rates which prevail during normal weather and different kinds of stormy weather may be estinated.

It is to be noted that the disaster sotrms such as major hurricane and tornadoes that occurs in the central region of Iraq are not lumped with the other less violent storms. This is due to the fact that such sotrms are relatively rare and give rise to component failure rates much higher than those experienced during "average" storms. One of these disaster storms occurred in the central region in June-1972, a major tornadoe strok the transmission line towers connecting Ramadi-Baghdad and led to the destruction of about twelve H.V. iron towers; and the supply was disconnected from Ramadi area for a period of three days.

The historical weather records which are obtained from the Meteorelogical Department of Baghdad for all major

weather stations are scanned to determine the total amount of time each year during which normal and storm conditions prevail. Now using the storm definition given in table(4.10), Iraq weather data are analysed for the period 1941-1970, and stormy weather is found to accupy an average of 0.40 % of the time of the year.

4.3.2 The system component Data for Reliability Calculation

4.3.2.1 Components failure rates

In order to evaluate the reliability measures for any given system, two basic forced outage failure rates must be evaluated for all types of equipments and lines in the system, these are:

a. The normal weather " permanent " forced outage (failure) rate λ_i where "i" labels the component type. This failure rate is expressed in units of failures per year of normal weather per unit of equipments or per killometer of line. It may be estimated as follows:

$$\lambda_i = \frac{D}{Y} \qquad \ldots\ldots(4.2)$$

where

D = Number of normal weather component failure during observation period.

Y = Total exposure times of normal weather during the observation period.

b. The stormy weather forced outage rate(λ'_i) obtained for components whose failure rate is affected by the weather. This failure rate has the unit of failures per year of stormy weather per unit of equipment or per kilometer of line and is estimated by the equation:

$$\lambda'_i = \frac{D'}{Y'} \qquad \ldots.(4.3)$$

where

D' = number of stormy weather component failures during observation period.

Y' = total exposure times of the stormy weather during observation period.

4.3.2.2 permanent outage distributions

The number and duration periods of the permanent outages that occurs in Iraq on line and equipment during five years for both stormy and normal weather periods are given in table (4.2). The distribution of component permanent failure time prevailing during normal and stormy weather are obtained from this table. permanent outage time for both normal and stormy period distribution is

seem to be exponential to a reasonable approximation.

Figs.(4.11 a,b,c)presents the results of this study for different regions of Iraqi. This result is very important so that any method or technique for reliability calculations can be applied, since all these techniques are based on the assumption of exponential failure distribution. Any other distribution may lead to complication in calculation of reliability of the system.

Using the above definitions and equations, the equivalent outage rates for all transmission system facilities in Iraq is estimated.

Table (4.11 A) presents the duration of the permanent outages during normal weather for the lines.

Table (4.11 B) gives these rates during normal weather as estimated from statistical analysis of the historical reports.

Table(4.12) gives the estimated failure rates per kilometers per year of 132 K.V. transmission and tie lines for both normal and stormy weather for different regions in Iraq.

Fig.(4.12) shows the histograms for failure rates for different regions of Iraq per kilometer per year of the transmission lines.

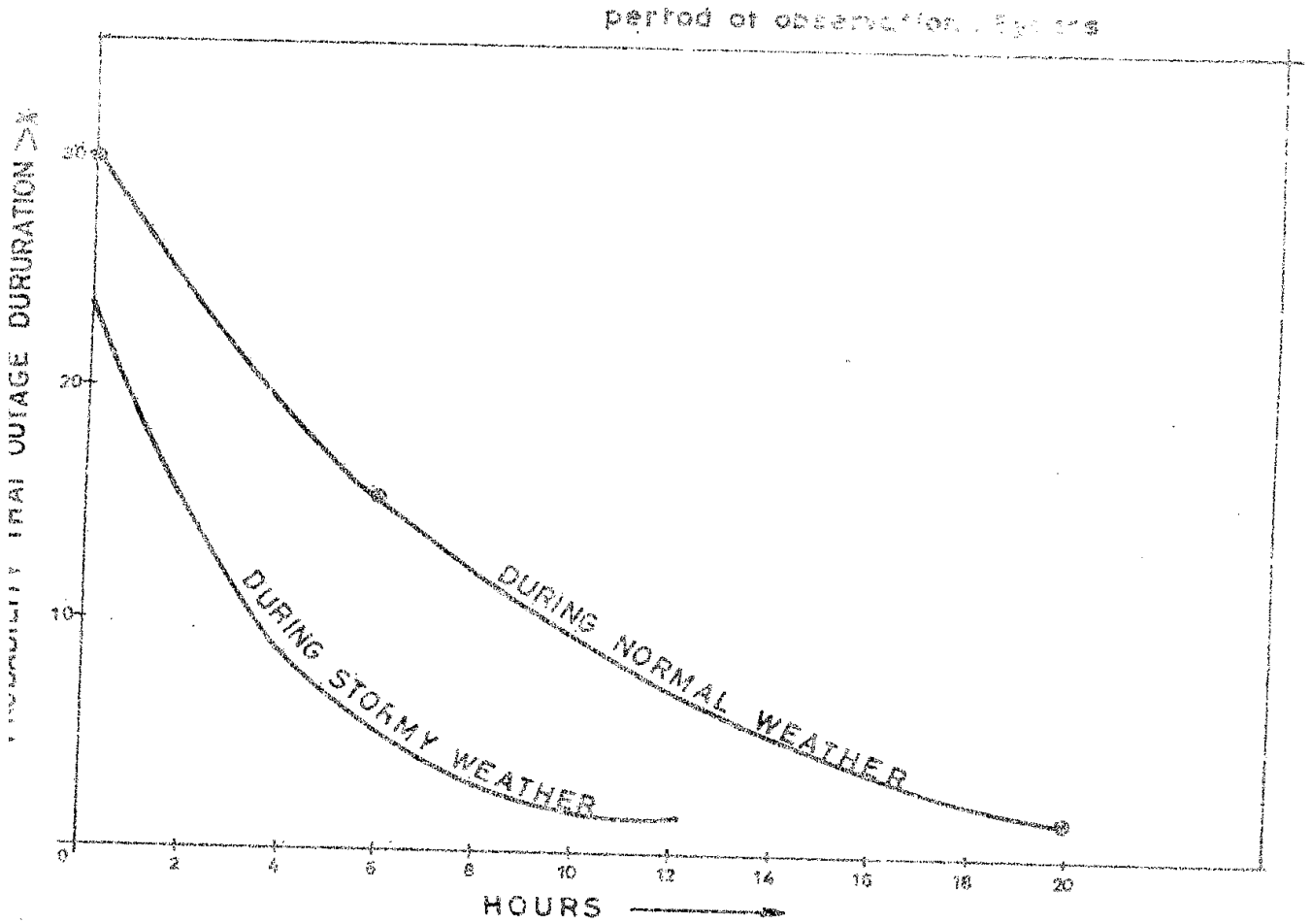


Fig. (4.11a)
PERMANENT OUTAGE TIME DISTRIBUTION FOR 132 KV O/HEAD TRANSMISSION LINE IN CENTRAL REGION OF IRAQ.

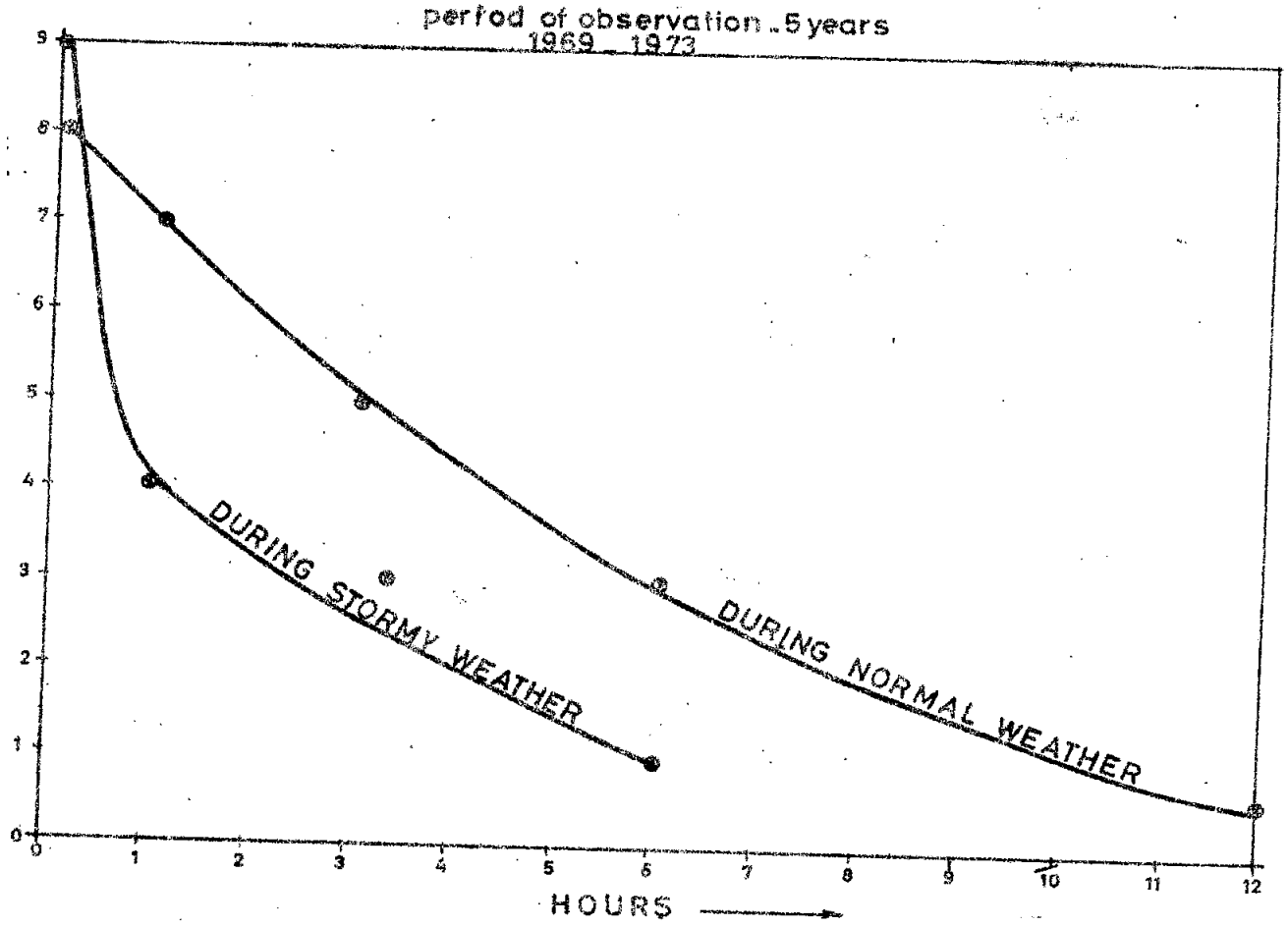


Fig. (4.11b)
PERMANENT OUTAGE TIME DISTRIB. FOR 132 KV OVER HEAD TRANSMISSION LINES IN SOUTH REGION IRAQ.

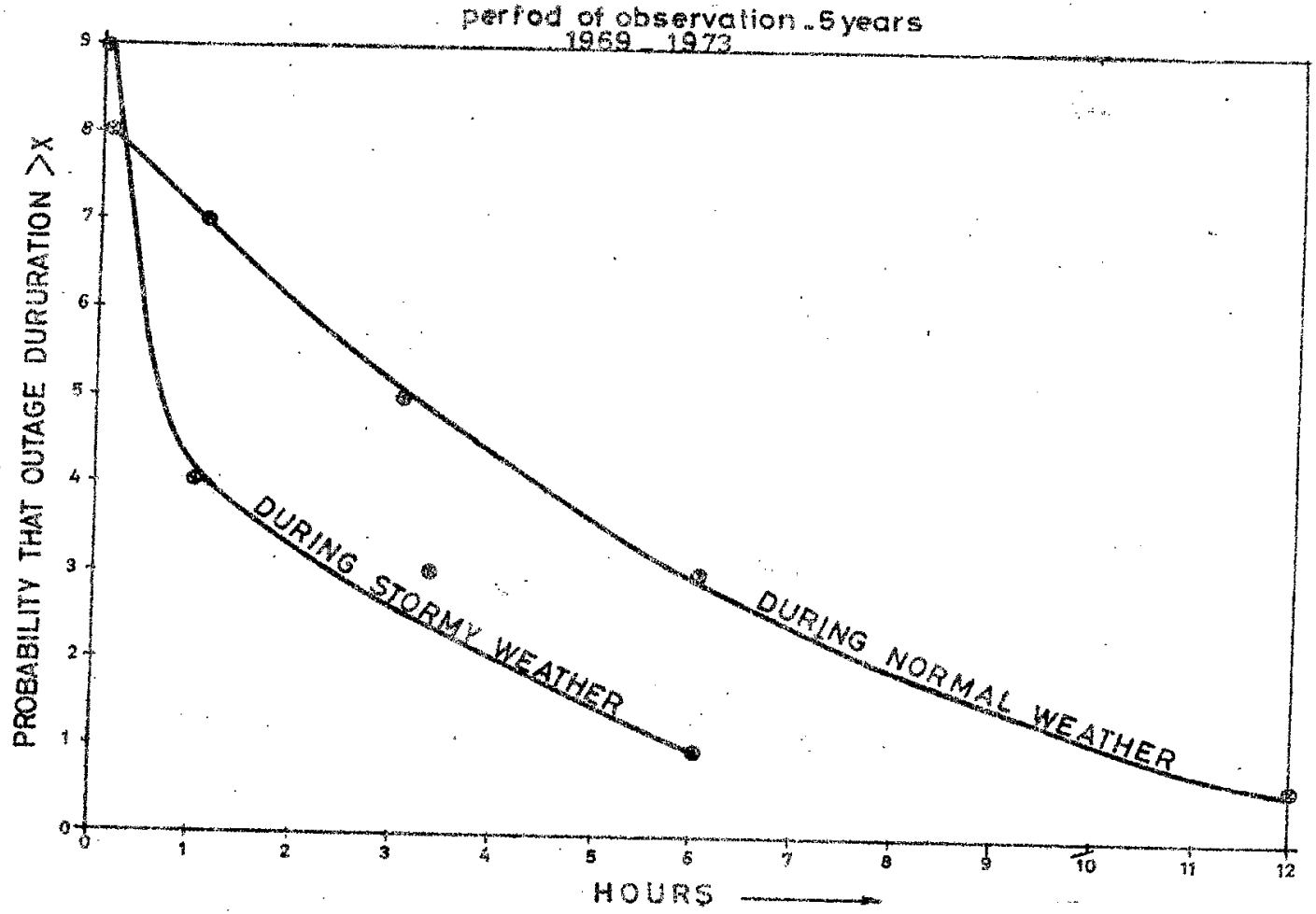


Fig. (4n
PERMANE
OUTAGE TIME
FOR 132 KV O\
TRANSMISSIO
IN SOUTH RE
IRAQ .

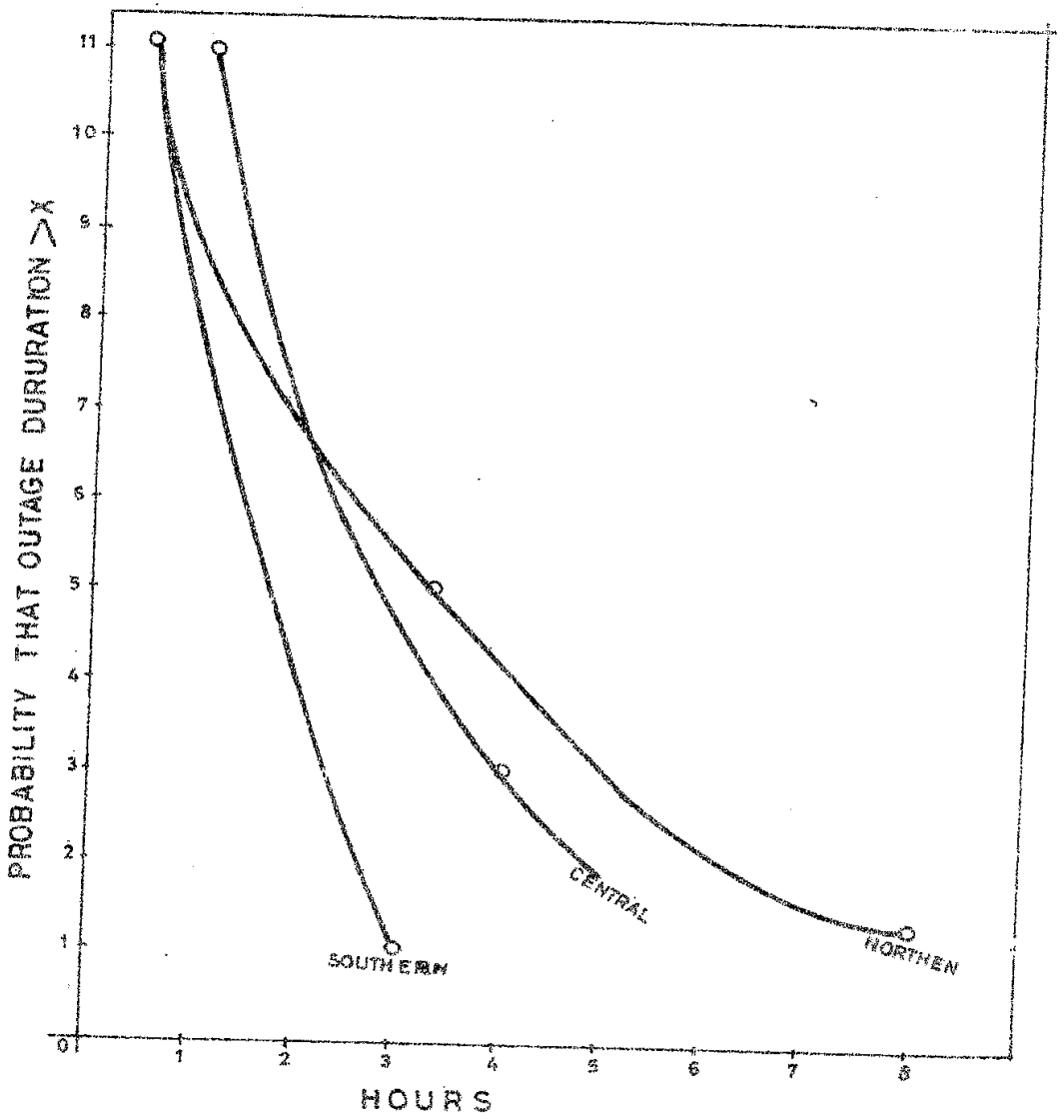


Fig. (4.11c) :
ANNUAL PERMANENT OUTAGE TIME DISTRIBUTION FOR 132 KV LINES FOR THREE REGIONS OF IRAQ DURING NORMAL WEATHER

TABLE 4.11A

DURATIONS OF THE PERMANENT OUTAGE DURING NORMAL WEATHER FOR 132 KV LINES

NUMBER OF FORCED OUTAGE DURING 5 YEAR		REGION		
		SOURTHERN IRAQ	CEMTRAL IRAQ	NORTHERN IRAQ
EXCEEDING	1 MIN	8.0	30.0	35
EXCC.	30 Min	8.0		33
EXCC.	1 HOUR	7.0	16.0	33
EXCC.	3 HOUR	5.0	16.0	30
EXCC.	6 HOUR	3.0	15.0	27
EXCC.	9 HOURS	1.0	12.0	18.
EXCC.	12 HOURS	1.0	9.0	9.0
EXCC.	15 HOURS	...	6.0	4.0
EXCC.	20 HOUR	...	2.0	2.0
EXCC.	30 HOUR		....	2.0

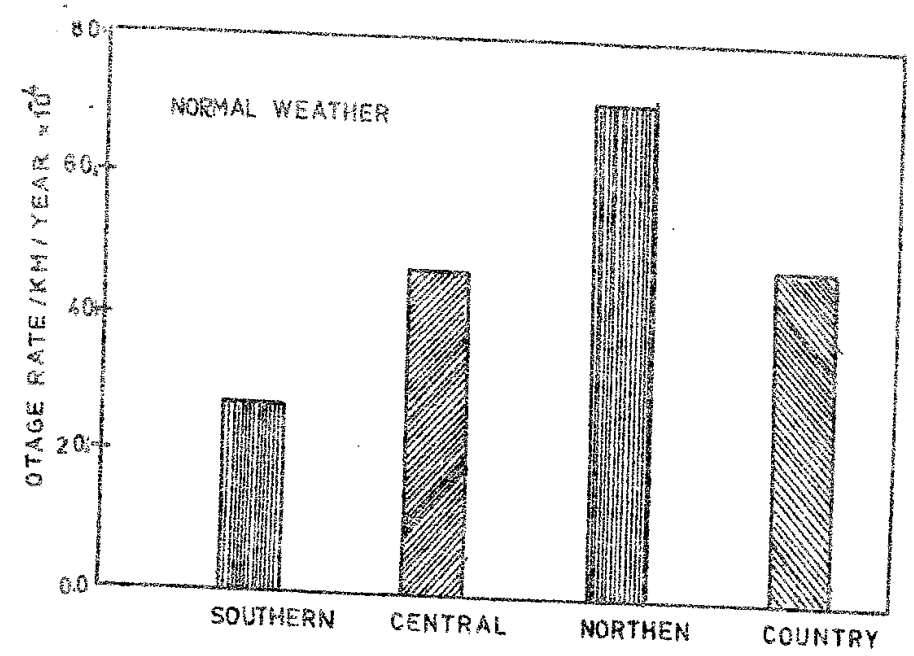
TABLE . 4.11 B

OUTAGE RATES FOR 132 KV TRANSMISSION FACILITIES IN IRAQ.

FACILITY	PERIOD SERVEYED YEARS	UNIT	OUTAGES / YEAR		
			NORTHEN REGION	CENTRAL REGION	SOUTHERN REGION
BUSES at Plant and Substations	5	Per Bus	1/10	7/32	1/20
Circuit Breakers	5	Per Breaker	4/40	5/100	3/66
Bulk Transmission Lines	5	Per KM OF T.Line	71.51×10^{-4}	55.20×10^{-4}	34.10×10^{-4}
132/33/11 KV Transformers	5	Per Transformer	10/14	26/40	15/20
ISOLATORS	5	Per Isolator	0.0	0.0	0.0

REGION	NORMAL WEATHER OUTAGE RATE/KM/Y	STORMY WEATH OUTAGE RATE /KM/YEAR	AVERAGE OUTAGE RATE/YEAR/KM FOR TWO STATE WEATHER
SOUTH REGION	27.01×10^{-4}	0.3121	34.1×10^{-4}
CENTRAL	47.95×10^{-4}	0.3197	55.2×10^{-4}
NORTHEN	71.51×10^{-4}	0.000	71.51×10^{-4}
COUNTRY	47.93×10^{-4}	0.2186	52.85×10^{-4}
TIE LINES CENTRAL REGION	67.99×10^{-4}	0.4910	79.14×10^{-4}

Table 4.12 FAILURE RATES PER KILLOMETTERS PER YEAR OF 132 KV . TRANSMISSION LINES IN DIFFERENT REGIONS OF IRAQ



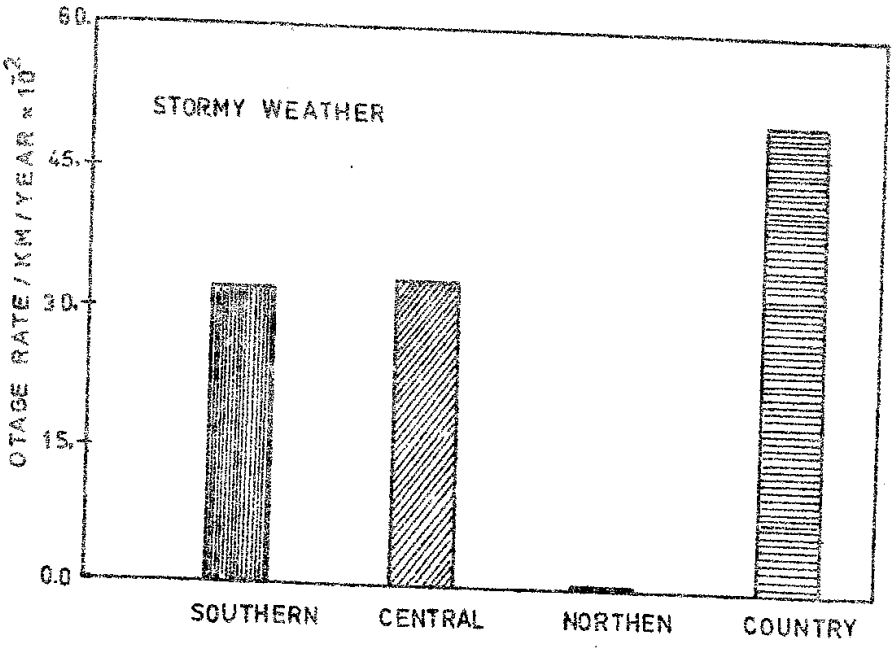


FIG [4.12] OUTAGE RATES PER KILOMETRE PER YEAR OF 132 K.V. LINES IN IRAQ

4.3.3 Digital Computer Studies of Iraq Transmission Line Reliability Evaluation

The statistical results obtained from tables which give the average failure rates during stormy and normal weather together with the equations that gives the relationships for outage rates, availability and expected outage time per year; are implemented in a computer program in order to evaluate the reliability indices for all transmission and tie lines available in the Iraqi system excluding the new constructed lines. The study includes only transmission lines which were built before the year 1970.

It must be noted that the study is divided into three sections corresponding to the three regions in Iraq. The reliability indices for all Iraq transmission and tie lines are given in tables (4.13, 4.14, 4.15, 4.16,4.17) as calculated for different restoring time starting from 2 hours up to 14 hours in step of four hours. The average restoring time of transmission and tie lines as obtained from statistical studies is approximately 6 hours. The listing of the computer programs are given in appendix (B9).

TAB[illegible]3)
SOUTHERN REGION T.LINES RELIABILITY MEASU[illegible]ES CALCULATION

AVERAGE REPARING TIME IN HOURS= 2.0

132.K.V. LINE	NORMAL.W OUT.R/Y	STORMY.W OUT.R/Y	EQUIVALENT OUT.R/Y	LINE AVA-ILABILITY	EXP.YEARLY OUT.TIME/Y
NAJIBIYA-HARTHA1	0.059436	6.868165	0.075112	0.999983	0.149331
NAJIBIYA-HARTHA2	0.059436	6.868165	0.075112	0.999983	0.149331
NAJIBIYA-SHUAIBA	0.062137	7.180354	0.078526	0.999982	0.156641
NAJIBIYA-SHUAIBA2	0.062137	7.180354	0.078526	0.999982	0.156641
SHUAIBA-ABUFLLUS1	0.097258	11.238815	0.122911	0.999972	0.244360
SHUAIBA-ABUFLLUS2	0.097258	11.238815	0.122911	0.999972	0.244360
SHUAIBA-UMQASSR 1	0.137783	15.921653	0.174123	0.999960	0.347743
SHUAIBA-UMQASSR 2	0.137783	15.921653	0.174123	0.999960	0.347743
AMMARA-HARTHA	0.383632	44.330879	0.484815	0.999889	0.969085
NASSIRIYA-SHUAIBA1	0.461980	53.384369	0.583827	0.999866	1.166453
NASSIRIYA-SHUAIBA2	0.461980	53.384369	0.583827	0.999866	1.166453
NASSIRIYA-RIFAI	0.216131	24.975143	0.273135	0.999937	0.545110
KUTT-AMMARA	0.510609	59.003776	0.645282	0.999852	1.289677
NASSIRIYA-SAMAWA	0.259357	29.970172	0.327762	0.999925	0.654759

AVERAGE REPARING TIME IN HOURS= 4.0

132.K.V. LINE	NORMAL.W OUT.R/Y	STORMY.W OUT.R/Y	EQUIVALENT OUT.R/Y	LINE AVA-ILABILITY	EXP.YEARLY OUT.TIME/Y
NAJIBIYA-HARTHA1	0.059436	6.868165	0.075112	0.999948	0.450081
NAJIBIYA-HARTHA2	0.059436	6.868165	0.075112	0.999948	0.450081
NAJIBIYA-SHUAIBA	0.062137	7.180354	0.078526	0.999946	0.470967
NAJIBIYA-SHUAIBA2	0.062137	7.180354	0.078526	0.999946	0.470967
SHUAIBA-ABUFLLUS1	0.097258	11.238815	0.122911	0.999915	0.737257
SHUAIBA-ABUFLLUS2	0.097258	11.238815	0.122911	0.999915	0.737257
SHUAIBA-UMQASSR 1	0.137783	15.921653	0.174123	0.999880	1.045317
SHUAIBA-UMQASSR 2	0.137783	15.921653	0.174123	0.999880	1.045317
AMMARA-HARTHA	0.383632	44.330879	0.484815	0.999668	2.907257
NASSIRIYA-SHUAIBA1	0.461980	53.384369	0.583827	0.999600	3.501449
NASSIRIYA-SHUAIBA2	0.461980	53.384369	0.583827	0.999600	3.501449
NASSIRIYA-RIFAI	0.216131	24.975143	0.273135	0.999813	1.637420
KUTT-AMMARA	0.510609	59.003776	0.645282	0.999358	3.870077
NASSIRIYA-SAMAWA	0.259357	29.970172	0.327762	0.999775	1.966367

TABLE(4.14)

CENTRAL IRAQ TRANSMISSION LINE RELIABILITY INDICIES EVALUATION

AVERAGE REPARI'G TIME IN HOURS= 2.0

132.K.V. LINE	NORMAL.W OUT.R/Y	STORMY.W OUT.R/Y	EQUIVALENT OUT.R/Y	LINE AVA-ILABILITY	EXP.YEARLY OUT.TIME/Y
SAMAWA-SHAMIYA	0.484369	32.291290	0.557600	0.999873	1.113195
SHAMIYA-HILLA	0.339537	22.635868	0.390872	0.999910	0.782160
KUT-AZIZIYA 1	0.412433	27.495552	0.474788	0.999891	0.949244
KUT-AZIZIYA 2	0.412433	27.495552	0.474788	0.999891	0.949244
AZIZIYA-S.BAGHDAD1	0.393250	26.216686	0.452705	0.999896	0.904340
AZIZIYA-S.BAGHDAD2	0.393250	26.216686	0.452705	0.999896	0.904340
DURA-HILLA 1	0.452237	30.149185	0.520611	0.999881	1.041140
DURA-HILLA2	0.452237	30.149185	0.520611	0.999881	1.041140
TAJI-RAMADI 1	0.502113	33.474235	0.578027	0.999868	1.154966
TAJI-RAMADI 2	0.502113	33.474235	0.578027	0.999868	1.154966
TAJI-SAMERRA 1	0.183197	12.213138	0.210894	0.999952	0.420842
TAJI-SAMERRA 2	0.183197	12.213138	0.210894	0.999952	0.420842
N.BAGHDAD-BAQUBA 1	0.250816	16.721130	0.288737	0.999934	0.576439
N.BAGHDAD-BAQUBA 2	0.250816	16.721130	0.288737	0.999934	0.576439

AVERAGE REPARING TIME IN HOURS= 6.0

132.K.V. LINE	NORMAL.W OUT.R/Y	STORMY.W OUT.R/Y	EQUIVALENT OUT.R/Y	LINE AVA-ILABILITY	EXP.YEARLY OUT.TIME/Y
SAMAWA-SHAMIYA	0.484369	32.291290	0.557600	0.999618	3.343763
SHAMIYA-HILLA	0.339537	22.635868	0.390872	0.999732	2.345438
KUT-AZIZIYA 1	0.412433	27.495552	0.474788	0.999675	2.847733
KUT-AZIZIYA 2	0.412433	27.495552	0.474788	0.999675	2.847733
AZIZIYA-S.BAGHDAD1	0.393250	26.216686	0.452705	0.999690	2.715111
AZIZIYA-S.BAGHDAD2	0.393250	26.216686	0.452705	0.999690	2.715111
DURA-HILLA 1	0.452237	30.149185	0.520611	0.999643	3.122377
DURA-HILLA2	0.452237	30.149185	0.520611	0.999643	3.122377
TAJI-RAMADI 1	0.502113	33.474235	0.578027	0.999604	3.465943
TAJI-RAMADI 2	0.502113	33.474235	0.578027	0.999604	3.465943
TAJI-SAMERRA 1	0.183197	12.213138	0.210894	0.999855	1.264615
TAJI-SAMERRA 2	0.183197	12.213138	0.210894	0.999855	1.264615
N.BAGHDAD-BAQUBA 1	0.250816	16.721130	0.288737	0.999802	1.731405
N.BAGHDAD-BAQUBA 2	0.250816	16.721130	0.288737	0.999802	1.731405

TABLE(4.15)

NORTHERN REGION T.LINES RELIABILITY INDICIES CALCULATION

AVERAGE REPARING TIME IN HOURS= 2.0

132.K.V. LINE	NORMAL.W OUT.R/Y	STORMY.W OUT.R/Y	EQUIVALENT OUT.R/Y	LINE AVAILABILITY	EXP.YEARLY OUT.TIME/Y
SAMERRA-DIBIS 1	1.265836	0.000000	1.265836	0.999711	2.531319
SAMERRA-DIBIS 2	1.265836	0.000000	1.265836	0.999711	2.531319
KIRKUK-SULAIMANIYA1	0.723743	0.000000	0.723743	0.999834	1.447363
KIRKUK-SULAIMANIYA2	0.723743	0.000000	0.723743	0.999834	1.447363
DIBIS-ERBIL 1	0.411217	0.000000	0.411217	0.999906	0.822887
DIBIS-ERBIL 2	0.411217	0.000000	0.411217	0.999906	0.822887
ERBIL-MOUSEL 1	0.673682	0.000000	0.673682	0.999846	1.346068
ERBIL-MOUSEL 2	0.673682	0.000000	0.673682	0.999846	1.346068
MOUSEL-HAMMAM 1	0.132304	0.000000	0.132304	0.999969	0.264201
MOUSEL-HAMMAM 2	0.132304	0.000000	0.132304	0.999969	0.264201
KIRKUK-DIBIS 1	0.293216	0.000000	0.293216	0.999933	0.586881
KIRKUK-DIBIS 2	0.293216	0.000000	0.293216	0.999933	0.586881

AVERAGE REPARING TIME IN HOURS= 6.0

132.K.V. LINE	NORMAL.W OUT.R/Y	STORMY.W OUT.R/Y	EQUIVALENT OUT.R/Y	LINE AVAILABILITY	EXP.YEARLY OUT.TIME/Y
SAMERRA-DIBIS 1	1.265836	0.000000	1.265836	0.999133	7.587691
SAMERRA-DIBIS 2	1.265836	0.000000	1.265836	0.999133	7.587691
KIRKUK-SULAIMANIYA1	0.723743	0.000000	0.723743	0.999504	4.340001
KIRKUK-SULAIMANIYA2	0.723743	0.000000	0.723743	0.999504	4.340001
DIBIS-ERBIL 1	0.411217	0.000000	0.411217	0.999718	2.466574
DIBIS-ERBIL 2	0.411217	0.000000	0.411217	0.999718	2.466574
ERBIL-MOUSEL 1	0.673682	0.000000	0.673682	0.999538	4.040294
ERBIL-MOUSEL 2	0.673682	0.000000	0.673682	0.999538	4.040294
MOUSEL-HAMMAM 1	0.132304	0.000000	0.132304	0.999909	0.792603
MOUSEL-HAMMAM 2	0.132304	0.000000	0.132304	0.999909	0.792603
KIRKUK-DIBIS 1	0.293216	0.000000	0.293216	0.999799	1.759600
KIRKUK-DIBIS 2	0.293216	0.000000	0.293216	0.999799	1.759600

TABLE(4.16)

CENTRAL IRAQ TIE LINES RELIABILITY INDICIES CALCULATION

AVERAGE REPARING TIME IN HOURS= 2.0

132.K.V. LINE	NORMAL.W OUT.R/Y	STORMY.W OUT.R/Y	EQUIVALENT OUT.R/Y	LINE AVA-ILABILITY	EXP.YEARLY OUT.TIME/Y
DURA-KADMIYA	0.161819	11.686985	0.188354	0.999957	0.375938
DURA-YARMUOK	0.097227	7.022011	0.113171	0.999974	0.225563
KADMIYA-TAJI	0.095188	6.874697	0.110797	0.999974	0.221385
YARMOUK-TAJI	0.096547	6.972907	0.112379	0.999974	0.225563
TAJI-GHAZALI	0.156380	11.294145	0.182023	0.999958	0.363407
TAJI-WAZIRIYA	0.118985	8.593372	0.138496	0.999968	0.275688
N.BAGHD.QUSAIBA 1	0.096547	6.972907	0.112379	0.999974	0.225563
N.BAGHD.QUSAIBA 2	0.096547	6.972907	0.112379	0.999974	0.225563
N.BAGHD.-GHAZALI	0.084989	6.138122	0.098925	0.999977	0.197367
N.BAGHD.-WAZIRIYA	0.104706	7.562167	0.121876	0.999972	0.242271
N.BAGHD.-S.BAGHD.1	0.046914	3.388243	0.054607	0.999987	0.107560
N.BAGHD.-S.BAGHD.2	0.046914	3.388243	0.054607	0.999987	0.107560

AVERAGE REPARING TIME IN HOURS= 6.0

132.K.V. LINE	NORMAL.W OUT.R/Y	STORMY.W OUT.R/Y	EQUIVALENT OUT.R/Y	LINE AVA-ILABILITY	EXP.YEARLY OUT.TIME/Y
DURA-KADMIYA	0.161819	11.686985	0.188354	0.999871	1.129904
DURA-YARMUOK	0.097227	7.022011	0.113171	0.999922	0.678777
KADMIYA-TAJI	0.095188	6.874697	0.110797	0.999924	0.664157
YARMOUK-TAJI	0.096547	6.972907	0.112379	0.999923	0.674600
TAJI-GHAZALI	0.156380	11.294145	0.182023	0.999875	1.091265
TAJI-WAZIRIYA	0.118985	8.593372	0.138496	0.999905	0.831241
N.BAGHD.QUSAIBA 1	0.096547	6.972907	0.112379	0.999923	0.674600
N.BAGHD.QUSAIBA 2	0.096547	6.972907	0.112379	0.999923	0.674600
N.BAGHD.-GHAZALI	0.084989	6.138122	0.098925	0.999932	0.594191
N.BAGHD.-WAZIRIYA	0.104706	7.562167	0.121876	0.999916	0.730991
N.BAGHD.-S.BAGHD.1	0.046914	3.388243	0.054607	0.999962	0.326857
N.BAGHD.-S.BAGHD.2	0.046914	3.388243	0.054607	0.999962	0.326857

TABLE(4.17)

IRAQ 132K.V.TRANSMISSION LINES RELIABILITY INDICIES

AVERAGE REPAIRING TIME IN HOURS= 2.0

132.K.V. LINE	NORMAL.W OUT.R/Y	STORMY.W OUT.R/Y	EQUIVALENT LINE AVAILABILITY OUT.R/Y		EXP.YEARLY OUT.TIME/Y
NAJIBIYA-HARTHA1	0.105446	4.809835	0.116277	0.999973	0.232872
NAJIBIYA-HARTHA2	0.105446	4.809835	0.116277	0.999973	0.232872
NAJIBIYA-SHUAIBA	0.110239	5.028464	0.121562	0.999972	0.242271
NAJIBIYA-SHUAIBA2	0.110239	5.028464	0.121562	0.999972	0.242271
SHUAIBA-ABUFLLUS1	0.172548	7.870638	0.190272	0.999956	0.379071
SHUAIBA-UMQASSR 1	0.244443	11.150072	0.269552	0.999938	0.539889
AMARA-HARTHA	0.680608	31.045299	0.750519	0.999828	1.500621
NASSIRIYA-SHUAIBA1	0.819605	37.385536	0.903794	0.999793	1.806593
NASSIRIYA-SHUAIBA2	0.819605	37.385536	0.903794	0.999793	1.806593
NASSIRIYA-RIFAI	0.383441	17.490310	0.422827	0.999903	0.843773
KUTT-AMMARA	0.905880	41.320854	0.998930	0.999772	1.996650
NASSIRIYA-SAMAWA	0.460129	20.988372	0.507393	0.999884	1.013989
SAMAWA-SHAMIYA	0.484094	22.081516	0.533820	0.999878	1.067247
SHAMIYA-HILLA	0.339345	15.478921	0.374202	0.999914	0.748744
KUT-AZIZIYA 2	0.412199	18.802082	0.454539	0.999896	0.908517
AZIZIYA-S.BACHDAD1	0.393027	17.927566	0.433398	0.999901	0.865702
AZIZIYA-S.BAGHDAD2	0.393027	17.927566	0.433398	0.999901	0.865702
DURA-HILLA 1	0.451981	20.616699	0.498408	0.999886	0.996236
DURA-HILLA2	0.451981	20.616699	0.498408	0.999886	0.996236
TAJI-RAMADI 1	0.501828	22.890441	0.553375	0.999873	1.105885
TAJI-RAMADI 2	0.501828	22.890441	0.553375	0.999873	1.105885
TAJI-SAMERRA 1	0.183093	8.351621	0.201900	0.999954	0.403089
TAJI-SAMERRA 2	0.183093	8.351621	0.201900	0.999954	0.403089
N.BAGHDAD-BAQUBA 1	0.250674	11.434289	0.276423	0.999936	0.553465
SAMERRA-DIBIS 1	0.848364	38.697311	0.935506	0.999786	1.869249
SAMERRA-DIBIS 2	0.848364	38.697311	0.935506	0.999786	1.869249
KIRKUK-SULAIMANIYA1	0.485053	22.125240	0.534877	0.999878	1.068291
KIRKUK-SULAIMANIYA2	0.485053	22.125240	0.534877	0.999878	1.068291
DIBIS-ERBIL 1	0.275598	12.571159	0.303907	0.999930	0.607767
DIBIS-ERBIL 2	0.275598	12.571159	0.303907	0.999930	0.607767
ERBIL-MOUSEL 1	0.451502	20.594841	0.497879	0.999886	0.994148
ERBIL-MOUSEL 2	0.451502	20.594841	0.497879	0.999886	0.994148
MOUSEL-HARTHA 1	0.088670	4.044533	0.097778	0.999977	0.196323
KIRKUK-DIBIS 1	0.196513	8.963783	0.216699	0.999950	0.432709
KIRKUK-DIBIS 2	0.196513	8.963783	0.216699	0.999950	0.432709

AVERAGE REPAIRING TIME IN HOURS= 6.0

132.K.V. LINE	NORMAL.W OUT.R/Y	STORMY.. OUT.R/Y	EQUIVALENT OUT.R/Y	LINE AVAILABILITY	EXP.YEARLY OUT.TIME/Y
NAJIBIYA-HARTHA1	0.105446	4.809835	0.116277	0.999920	0.697574
NAJIBIYA-HARTHA2	0.105446	4.809835	0.116277	0.999920	0.697574
NAJIBIYA-SHUAIBA	0.110239	5.028464	0.121562	0.999916	0.728902
NAJIBIYA-SHUAIBA2	0.110239	5.028464	0.121562	0.999916	0.728902
SHUAIBA-ABUFLUS1	0.172548	7.870638	0.190272	0.999869	1.141391
SHUAIBA-UMQASSR 1	0.244443	11.150072	0.269552	0.999815	1.617579
AMMARA-HARTHA	0.680608	31.045299	0.750519	0.999486	4.500819
NASSIRIYA-SHUAIBA1	0.819605	37.385536	0.903794	0.999381	5.418735
NASSIRIYA-SHUAIBA2	0.819505	37.385536	0.903794	0.999381	5.418735
NASSIRIYA-RIFAI	0.383441	17.490310	0.422827	0.999710	2.535496
KUT-AMMARA	0.905880	41.320854	0.998930	0.999316	5.988908
NASSIRIYA-SAMAWA	0.460129	20.988372	0.507393	0.999652	3.043013
SAMAWA-SHAMIYA	0.484094	22.081516	0.533820	0.999634	3.201742
SHAMIYA-HILLA	0.339345	15.478921	0.374202	0.999743	2.244143
KUT-AZIZIYA 2	0.412199	18.802082	0.454539	0.999688	2.725553
AZIZIYA-S.BAGHDAD1	0.393027	17.927566	0.433398	0.999703	2.600241
AZIZIYA-S.BAGHDAD2	0.393027	17.927566	0.433398	0.999703	2.600241
DURA-HILLA 1	0.451981	20.616699	0.498408	0.999658	2.989755
DURA-HILLA2	0.451981	20.616699	0.498408	0.999658	2.989755
TAJI-RAMADI 1	0.501828	22.890441	0.553375	0.999621	3.318701
TAJI-RAMADI 2	0.501828	22.890441	0.553375	0.999621	3.318701
TAJI-SAMERRA 1	0.183093	8.351621	0.201900	0.999861	1.210313
TAJI-SAMERRA 2	0.183093	8.351621	0.201900	0.999861	1.210313
N.BAGHDAD-BAQUBA 1	0.250674	11.434289	0.276423	0.999810	1.658306
SAMERRA-DIBIS 1	0.848364	38.697311	0.935506	0.999359	5.608793
SAMERRA-DIBIS 2	0.848364	38.697311	0.935506	0.999359	5.608793
KIRKUK-SULAIMANIYA1	0.485053	22.125240	0.534877	0.999634	3.206964
KIRKUK-SULAIMANIYA2	0.485053	22.125240	0.534877	0.999634	3.206964
DIBIS-ERBIL 1	0.275598	12.571159	0.303907	0.999792	1.822257
DIBIS-ERBIL 2	0.275598	12.571159	0.303907	0.999792	1.822257
ERBIL-MOUSEL 1	0.451502	20.594841	0.497879	0.999659	2.986622
ERBIL-MOUSEL 2	0.451502	20.594841	0.497879	0.999659	2.986622
MOUSEL-HAMMAM 1	0.088670	4.044633	0.097778	0.999933	0.586881
KIRKUK-DIBIS 1	0.196513	8.963783	0.216699	0.999851	1.300120
KIRKUK-DIBIS 2	0.196513	8.963783	0.216699	0.999851	1.300120

AVERAGE REPARING TIME IN HOURS= 10.0

132.K.V. LINE	NORMAL.W OUT. /Y	STORMY.W OUT.R/Y	EQUIVALENT OUT.R/Y	LINE AVA-ILABILITY	EXP.YEARLY OUT.TIME/Y
NAJIBIYA-HARTHA1	0.105446	4.809835	0.116277	0.999867	1.162276
NAJIBIYA-HARTHA2	0.105446	4.809835	0.116277	0.999867	1.162276
NAJIBIYA-SHUAIBA	0.110239	5.028464	0.121562	0.999861	1.214490
NAJIBIYA-SHJAIBA2	0.110239	5.028464	0.121562	0.999861	1.214490
SHUAIBA-ABUFLLUS1	0.172548	7.870638	0.190272	0.999783	1.901622
SHUAIBA-UMQASSR 1	0.244443	11.150072	0.269557	0.999692	2.695270
AMMARA-HARTHA	0.680608	31.045299	0.750519	0.999144	7.498928
NASSIRIYA-SHUAIBA1	0.819605	37.385536	0.903794	0.998969	9.027744
NASSIRIYA-SHUAIBA2	0.819605	37.385536	0.903794	0.998969	9.027744
NAS IRIYA-RIFAI	0.383441	17.490310	0.422827	0.999517	4.226175
KUTT-AMMARA	0.905880	41.320854	0.998930	0.998861	9.978033
NASSIRIYA-SAMAWA	0.460129	20.988372	0.507393	0.999421	5.070992
SAMAWA-SHAMIYA	0.484094	22.081516	0.533820	0.999391	5.335193
SHAMIYA-HILLA	0.339345	15.478921	0.374202	0.999573	3.740587
KUT-AZIZIYA 2	0.412199	18.802082	0.454539	0.999481	4.542590
AZIZIYA-S.BAGHDAD1	0.393027	17.927566	0.433398	0.999505	4.331646
AZIZIYA-S.BAGHDAD2	0.393027	17.927566	0.433398	0.999505	4.331646
DURA-HILLA 1	0.451981	20.616699	0.498408	0.999431	4.980140
DURA-HILLA2	0.451981	20.616699	0.498408	0.999431	4.980140
TAJI-RAMADI 1	0.501828	22.890441	0.553375	0.999368	5.530472
TAJI-RAMADI 2	0.501828	22.890441	0.553375	0.999368	5.530472
TAJI-SAMERRA 1	0.183093	8.351621	0.201900	0.999769	2.017536
TAJI-SAMERRA 2	0.183093	8.351621	0.201900	0.999769	2.017536
N.BAGHDAD-BAQUBA 1	0.250674	11.434289	0.276423	0.999684	2.763147
SAMERRA-DIBIS 1	0.848364	38.697311	0.935506	0.998933	9.345203
SAMERRA-DIBIS 2	0.848364	38.697311	0.935506	0.998933	9.345203
KIRKUK-SULAIMANIYA1	0.485053	22.125240	0.534877	0.999389	5.345636
KIRKUK-SULAIMANIYA2	0.485053	22.125240	0.534877	0.999389	5.345636
DIBIS-ERBIL 1	0.275598	12.571159	0.303907	0.999653	3.037791
DIBIS-ERBIL 2	0.275598	12.571159	0.303907	0.999653	3.037791
ERBIL-MOUSEL 1	0.451502	20.594841	0.497879	0.999432	4.975963
ERBIL-MOUSEL 2	0.451502	20.594841	0.497879	0.999432	4.975963
MOUSEL-HAMMAM 1	0.088673	4.044633	0.097778	0.999888	0.978484
KIRKUK-DIBIS 1	0.196513	8.963783	0.216690	0.999752	2.166867
KIRKUK-DIBIS 2	0.196513	8.963783	0.216690	0.999752	2.166867

AVERAGE REPAIRING TIME (HOURS) 132.K.V. LINE	NORMAL.W OUT.R/Y	STORMY.W OUT.R/Y	EQUIVALENT OUT.R/Y	LINE AVAILABILITY	EXP.YEARLY OUT.TIME/Y
NAJIBIYA-HARTHA1	0.105446	4.809835	0.116277	0.999814	1.626978
NAJIBIYA-HARTHA2	0.105446	4.809835	0.116277	0.999814	1.626978
NAJIBIYA-SHUAIBA	0.110239	5.028464	0.121562	0.999805	1.701121
NAJIBIYA-SHUAIBA2	0.110239	5.028464	0.121562	0.999805	1.701121
SHUAIBA-ABUFLLUS1	0.172548	7.870638	0.190272	0.999696	2.661853
SHUAIBA-UMQASSR 1	0.244443	11.150072	0.269552	0.999569	3.771915
AMMARA-HARTHA	0.680608	31.045299	0.750519	0.998802	10.494949
NASSIRIYA-SHUAIBA1	0.819605	37.385536	0.903794	0.998557	12.633621
NASSIRIYA-SHUAIBA2	0.819605	37.385536	0.903794	0.998557	12.633621
NASSIRIYA-RIFAI	0.383441	17.490310	0.422827	0.999324	5.914765
UTT-AMMARA	0.905880	41.320854	0.998930	0.998406	13.962980
NASSIRIYA-SAMAWA	0.460129	20.988372	0.507393	0.999189	7.096882
SAMAWA-SHAMIYA	0.484094	22.081516	0.533820	0.999147	7.467599
SHAMIYA-HILLA	0.339345	15.478921	0.374202	0.999402	5.234943
KUT-AZIZIYA 2	0.412199	18.802082	0.454539	0.999274	6.358581
AZIZIYA-S.BAGHDAD1	0.393027	17.927566	0.433398	0.999307	6.063052
AZIZIYA-S.BAGHDAD2	0.393027	17.927566	0.433398	0.999307	6.063052
DURA-HILLA 1	0.451981	20.616699	0.498408	0.999204	6.970525
DURA-HILLA2	0.451981	20.616699	0.498408	0.999204	6.970525
TAJI-RAMADI 1	0.501828	22.890441	0.553375	0.999116	7.740155
TAJI-RAMADI 2	0.501828	22.890441	0.553375	0.999116	7.740155
TAJI-SAMERRA 1	0.183093	8.351621	0.201900	0.999677	2.824759
TAJI-SAMERRA 2	0.183093	8.351621	0.201900	0.999677	2.824759
N.BAGHDAD-BAQUBA 1	0.250674	11.434289	0.276423	0.999558	3.867989
SAMERRA-DIBIS 1	0.848364	38.697311	0.935506	0.998507	13.076393
SAMERRA-DIBIS 2	0.848364	38.697311	0.935506	0.998507	13.076393
KIRKUK-SULAIMANIYA1	0.485053	22.125240	0.534877	0.999146	7.481175
KIRKUK-SULAIMANIYA2	0.485053	22.125240	0.534877	0.999146	7.481175
DIBIS-ERBIL 1	0.275598	12.571159	0.303907	0.999514	4.252282
DIBIS-ERBIL 2	0.275598	12.571159	0.303907	0.999514	4.252282
ERBIL-MOUSEL 1	0.451502	20.594841	0.497879	0.999205	6.964260
ERBIL-MOUSEL 2	0.451502	20.594841	0.497879	0.999205	6.964260
MOUSEL-HAMAM 1	0.080670	3.044033	0.077778	0.999843	1.369042
KIRKUK-DIBIS 1	0.196513	8.963783	0.216699	0.999653	3.032570
KIRKUK-DIBIS 2	0.196513	8.963783	0.216699	0.999653	3.032570

4.4 The Markov Technique As a Mean of Determination of Iraqi Transmission System Reliability

The primary informations about Iraq transmission system are now available so that the powerfull technique of Markovian can be applied. This technique is now used to evaluate the reliability measure of two typical parallel lines in the southern region of Iraq Connecting Nassiriya-shuaiba substations with a length of 171 Km. Each of these lines passes through a region of humid at winter and dusty in summer. Fig.(4.12) shows the variation of humidity and dust sotrms at the region of study. The necessary statistical informations for this study are obtained from the previous sections together with the following table(4.18)

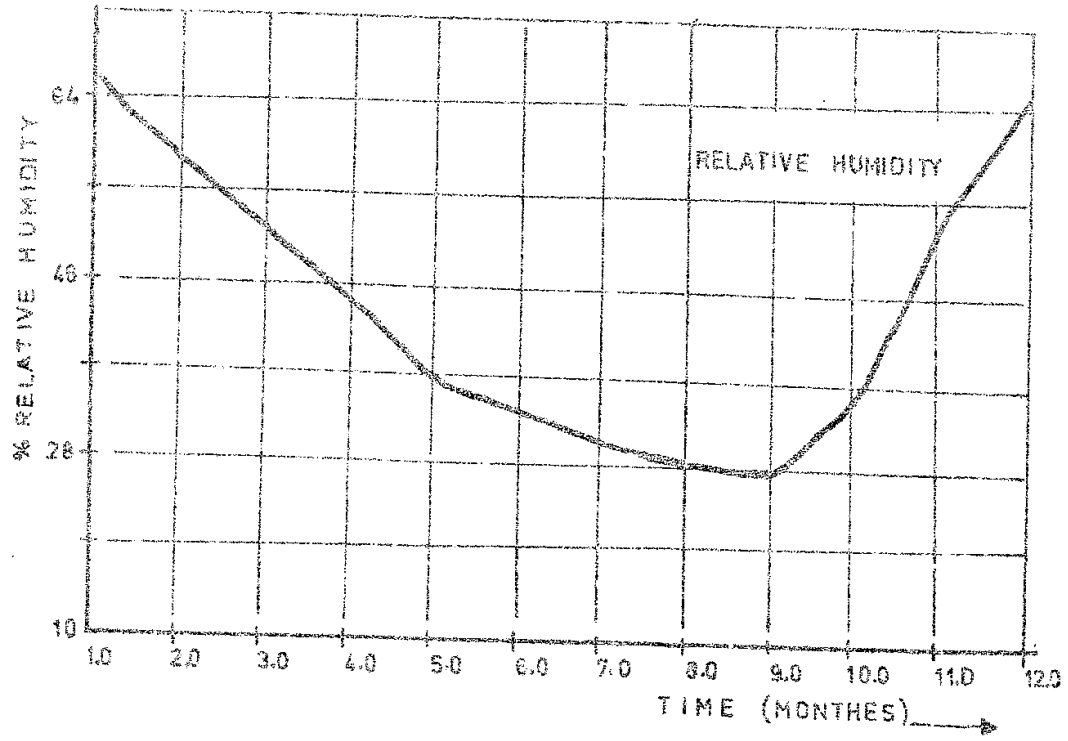
Table (4.18)

Statistical data for shuaiba-Nassiriya

132 K.V. T.Line

NORMAL WEATHER OUTAGE RATE/YAER	0.50115
STURMY WEATHER OUTAGE RATE/YEAR	173.733
AVERAGE OUTAGE RATE/YEAR	0.890
EXPECTED STORMY WEATHER PERIOD	1.5 (HR)
EXPECTED NORMAL WEATHER PERIOD	650.0 (HR)

The state space diagram for these two parallel lines are now constructed in fig.(4.13)..



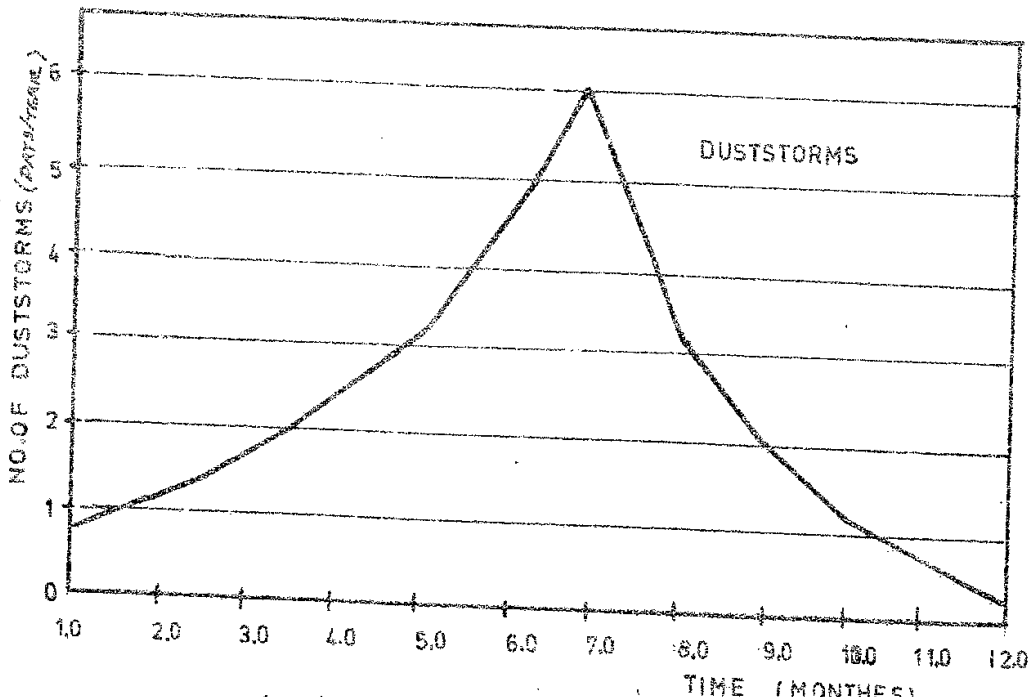
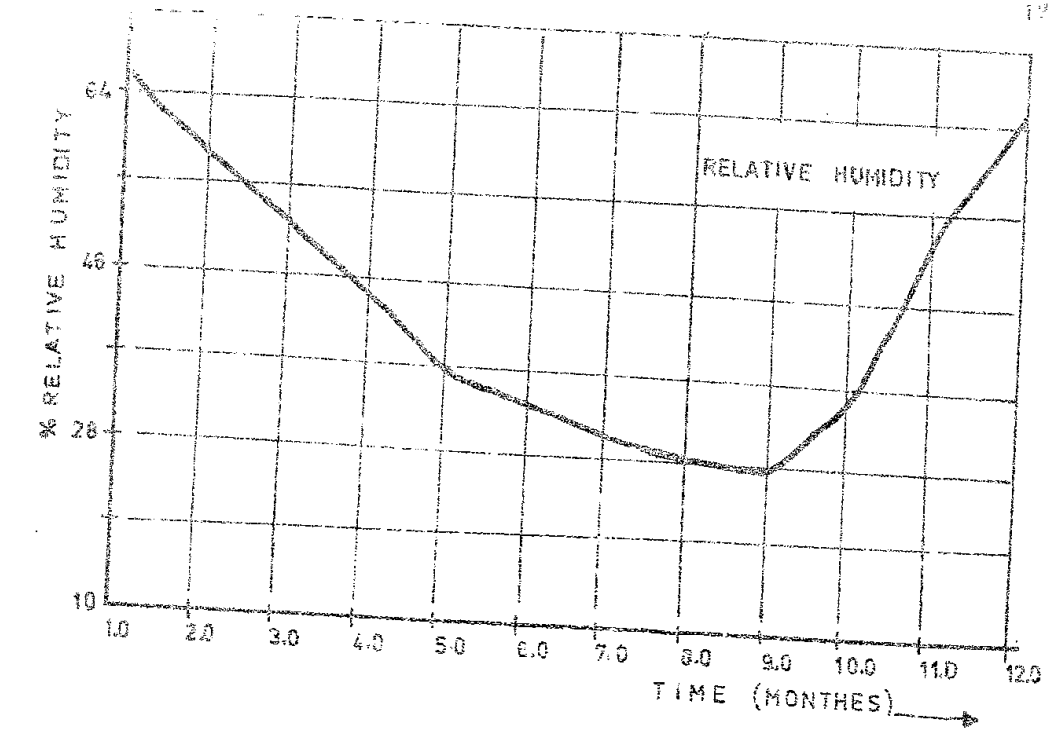


FIG. (4.12) : VARIATION OF DUST STORMS AND RELATIVE HUMIDITY AT NASSIRIYA.



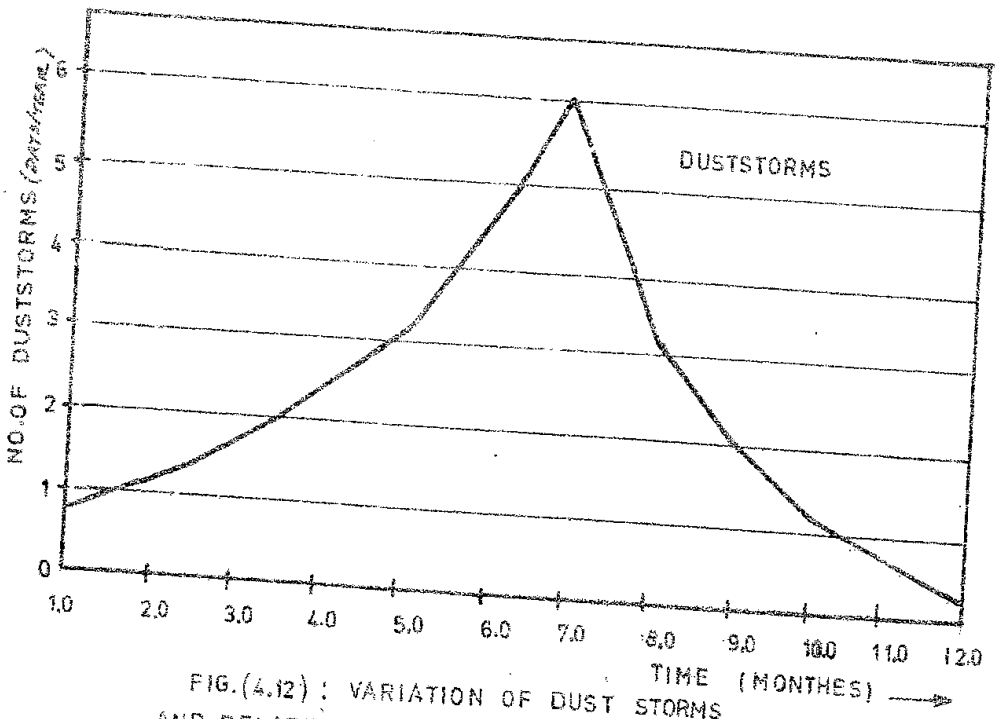
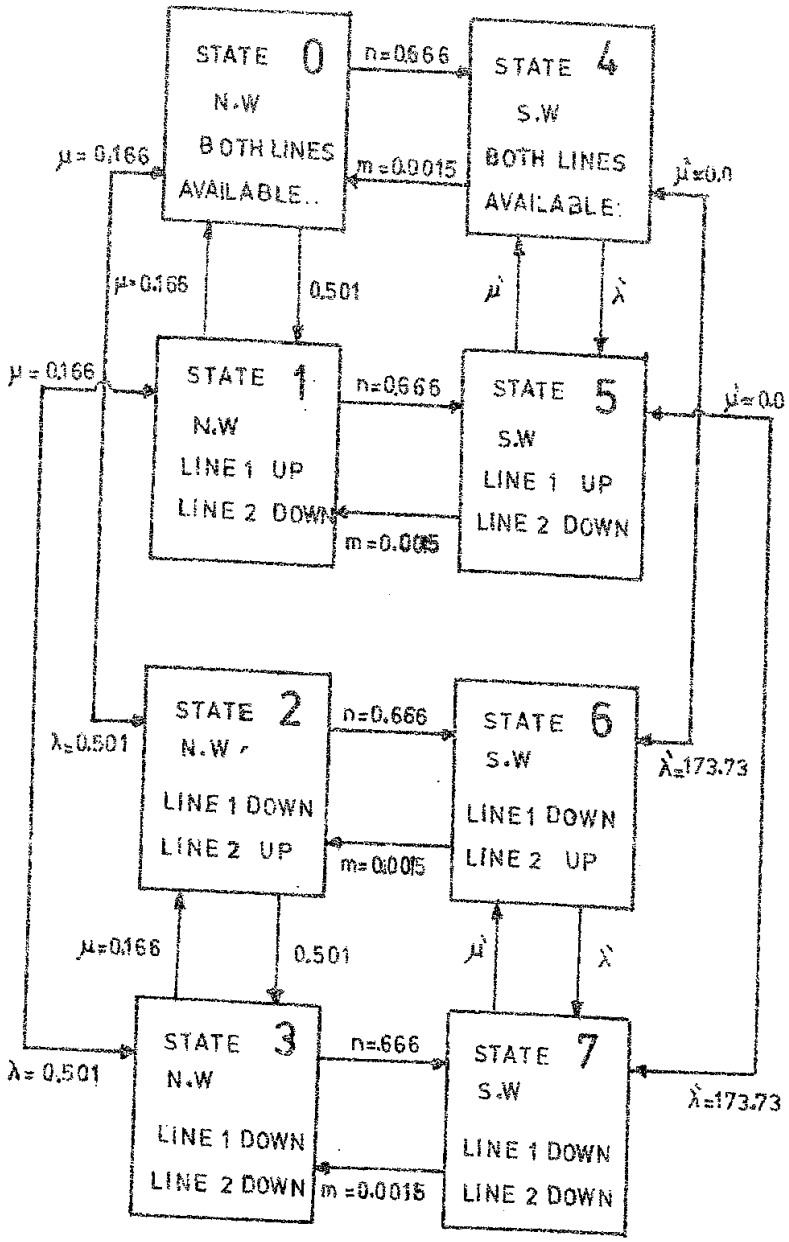


FIG. (4.12) : VARIATION OF DUST STORMS AND RELATIVE HUMIDITY AT NASSIRIYA - SHUAIBA REGION



FIG(4.13) STATE SPACE DIAGRAM FOR NASSIRYA – SHUAIBA 132.K.V. DOUBLE C.C.T. SINGLE TOWER LINE ENCOUNTERING 2-STATES FLUCTUATING ENVIRONMENT IN THE SOUTH REGION OF IRAQ

Proceeding directly from this diagram, the stochastic transitional probability matrix given by Markov can be found, and the system differential equations in matrix form are:

$$[\,P'_{(t)}\,] = [\,P_{(t)}\,] \begin{bmatrix} A_1 & A_2 \\ A_3 & A_4 \end{bmatrix} \quad ..(4.4)$$

where :

A_1 and A_4 are matrices as shown in table(4.19)

A_2 and A_3 are as follows:

$$A_2 = n \cdot [I]$$

$$A_3 = m. [I]$$

Now assuming these two lines are fully redundant, then the probability of the system occupying the failed state is obtained by summing the limiting state probabilities for state 3 and 7 given in fig. (4.13). The failure rate and mean time to failure are obtained by truncating the stochastic transitional probability matrix by ignoring state 3 and 7. A computer programme is developed in this thesis to solve the truncated matrix and to obtain the rate of failure and mean time to failure. This programme is given in appendix (B_{10}). The programme utilizes the statistical results and meteorological information given in previous sections.

Southern Iraq weather data are analysed for the period 1941-1973. Storms are found to occupy an average of 0.42% of the time of the year. It is also seen that the weather distribution in this region is exponential.

All disaster storms such as major hurricanes and tornadoes are not lumped with the other average storms during the study period.

Table (4.19)

Partitioned Matrices For Nassiriya-Shuaiba Line assuming

$\lambda_1 = \lambda_2 = \lambda$, $\mu_1 = \mu_2 = \mu$, $\lambda'_1 = \lambda'_2 = \lambda'$ and

$\mu'_1 = \mu'_2 = \mu'$

$$A_1 = \begin{bmatrix} (-2\lambda - n) & \lambda & \lambda & 0 \\ \mu & (-\lambda - \mu - n) & 0 & \lambda \\ \mu & 0 & (-\mu - \lambda - n) & \lambda \\ 0 & \mu & \mu & (-2\mu - n) \end{bmatrix}$$

$$A_3 = \begin{bmatrix} (-2\lambda' - m) & \lambda' & \lambda' & 0 \\ \mu' & (-\lambda' - \mu' - m) & 0 & \lambda' \\ \mu' & 0 & (-\lambda' - \mu' - n) & \lambda' \\ 0 & \mu' & \mu' & (-2\mu' - n) \end{bmatrix}$$

The result obtained from treating the data for these two lines, assuming no repair during stormy period, are given in table (4.20), It is noted that at normal weather i.e 0 % Stormy weather failure, the mean time to failure of the system is more sensitive to the variation of the repairing time.i.e, decreasing the duration of repair from 8 hours to 4 hours, would give the MTTF of 676.5 hours approximately which is nearly half its original value, while for high storm weather percentage the effect of restoring or repairing time is negligably small. This can be easily seen from fig.(4.14,4.15).

4.5 Comparison Between Markov and Frequency and Duration Method

The approximate equations describing four phases of failure which include the bunching effect of the fluctuating environment (given in subsection 3.2.2) are implemented in the segment of computer programme to analyse the same data for Nassiriya- Shuaiba double circuit 132 K.V. line, and to varify the results which are obtained by the exact Markov technique.

The approximation done in this method are as follows:

For phase I :

TABLE 4.20

Equivalent Failure Rate of System with Paramters λ_{av}

Component Annual Failure Rate = 0.89, Failure/Year

S = 1.5 H, N = 650 H (Unit In Failure/Year)

Stormy Weather Failure (Percent)	Durations of Repair Hours	Equivalent Failure Rate For Two parallel Line X 10^{-4}	Meen Time to Failure Starting From Normal Weather State 0
0	4.0	7.389748	1353.226
	6.0	11.086140	902.026
	8.0	14.776180	676.764
20	4.0	53.58003	186.636
	6.0	57.22710	174.751
	8.0	60.85535	164.432
40	4.0	185.15340	54.0092
	6.0	188.63220	53.0132
	8.0	192.10060	52.05606
60	4.0	392.4383	25.48171
	6.0	395.6645	25.27393
	8.0	398.8850	25.069888
80	4.0	666.9312	14.99405
	6.0	669.8322	14.92000
	8.0	672.7290	14.86000
100	4.0	1001.003	9.98940
	6.0	1003.531	9.96400
	8.0	1006.550	9.93900

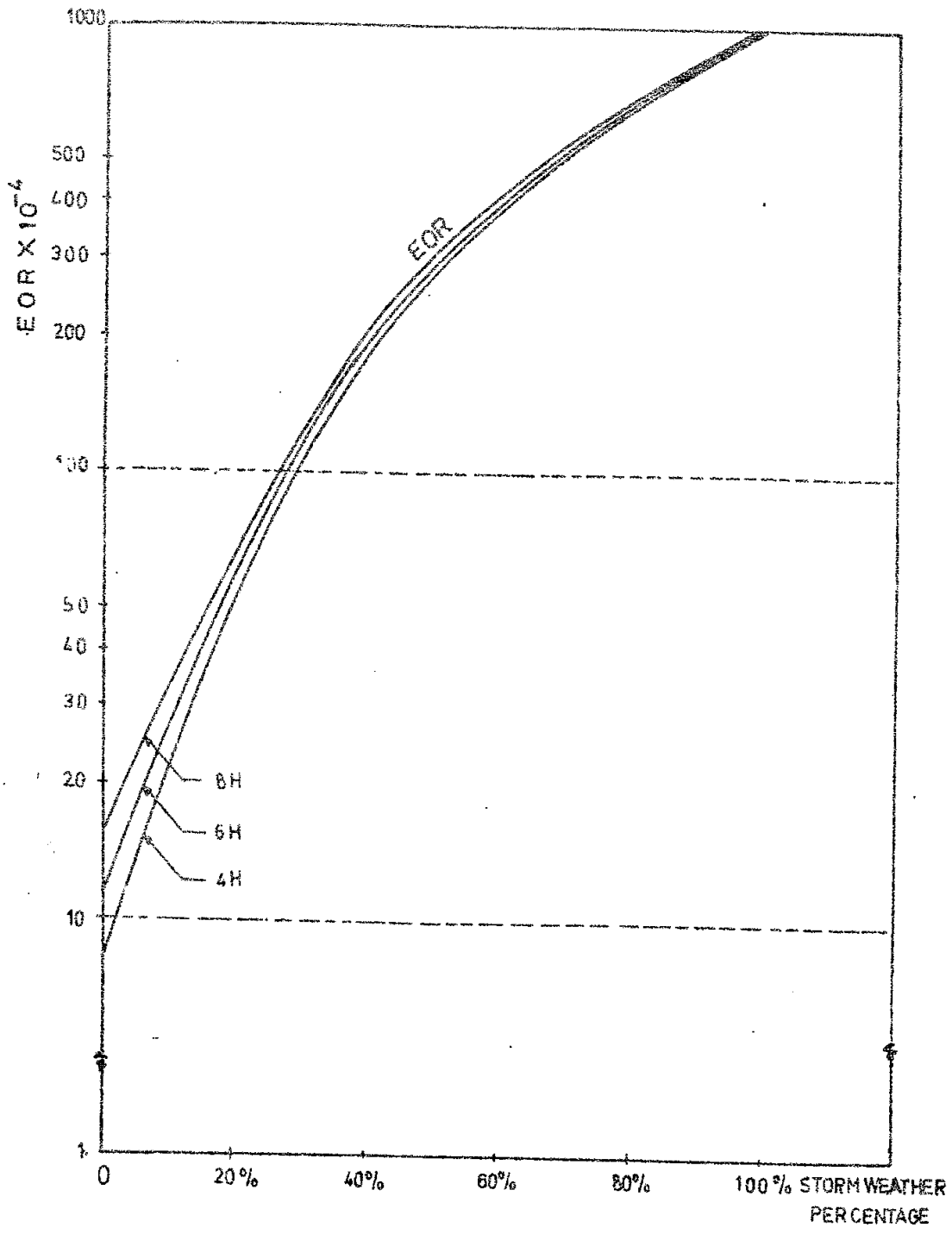


Fig.(4.14): EQUIVALENT OUTAGE RATE VARIATION WITH THE PERCENTAGE STORM WEATHER FAILURE FOR NASSIRYA - SHUAIBA LINE

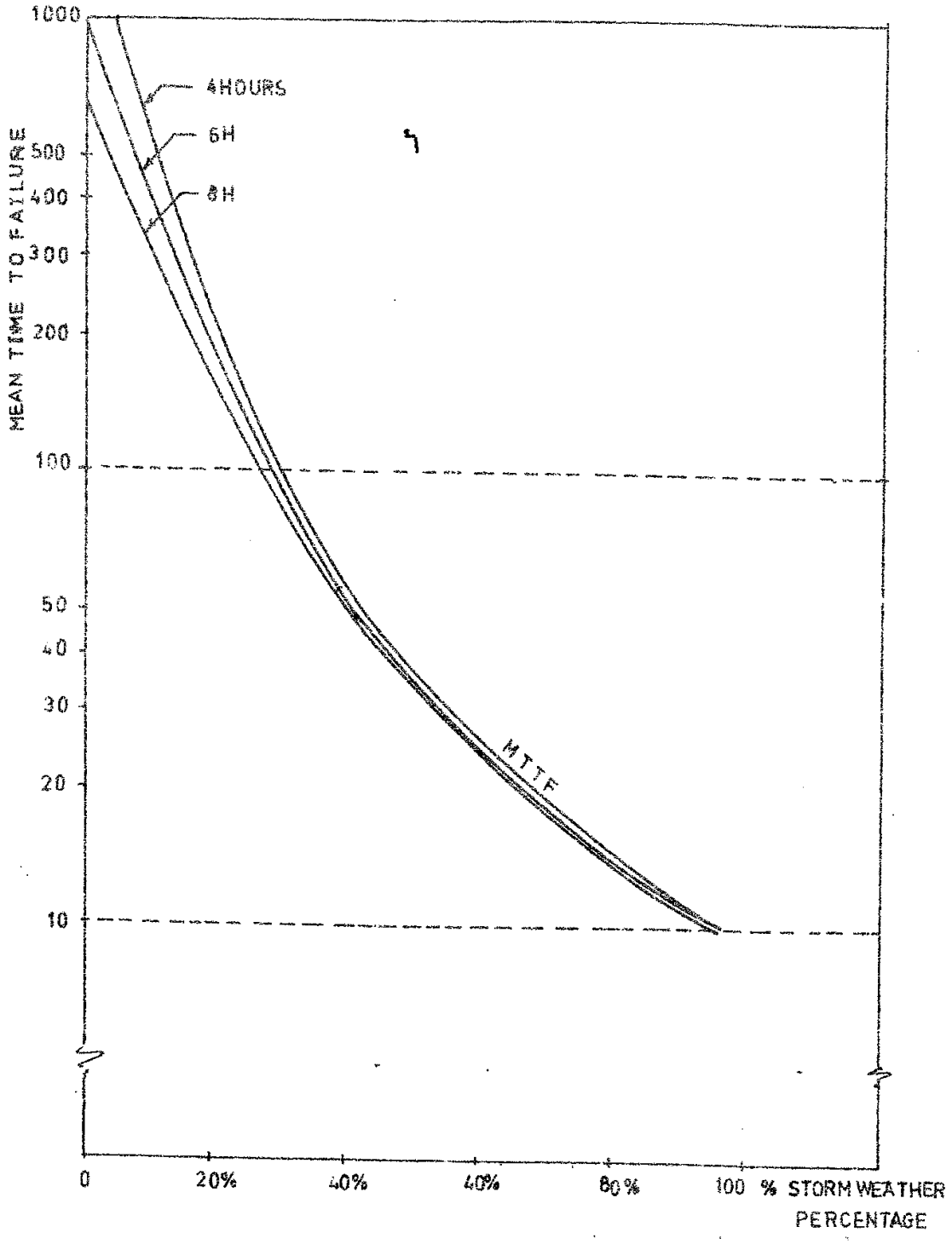


Fig (4.15): MTTF VARIATION WITH THE STORM FAILURE PERCENTAGE FOR NASSIRIYA_SHUAIBA LINE

a. The probability that a storm does not occur while the first line is being repaired is :

$$e^{-1/\mu_1 N} \simeq 1 - 1/\mu_1 N) \qquad \ldots\ldots(4.5)$$

b. The probability that the second line fails during the repair period of line number 1 is :

$$1 - e^{-\lambda_2/\mu_1} \simeq \lambda_2/\mu_1 \quad \ldots(4.6)$$

For phase II :

a. The probability that a storm occurrs while line number 1 is being repaired is :

$$1/\mu_1 N \simeq 1 - e^{-(1/\mu_1 N)} \quad \ldots(4.7)$$

b. The probability that line number 2 fails during storm is

$$1 - e^{\lambda_2 S} \simeq \lambda_2 S \qquad \ldots\ldots(4.8)$$

c. The two failure rates for the two lines are equal i.e

$$\lambda_1 \simeq \lambda_2$$

No repair take place during the stormy period and

$$\mu_1 = \mu_2.$$

e. Maintenance outages are not added to the analysis.

Thus the complete failure rate expression including each of the four phases is as follows:

$$\lambda_T = \frac{N}{N+S}\left[2\lambda^2/\mu + \frac{4S}{N}(\lambda\lambda'/\mu) + \frac{2S^2}{N}\lambda\lambda'\right] \ldots.(4.9)$$

This final form of the approximate formula is used now to evaluate the reliability indices for the Nassiriya-Shuaiba line as follows:

$$MTTF=1/\lambda_T = \frac{N+S}{N} / \{ 2\lambda^2/\mu + \frac{4S}{N}(\lambda \lambda'/\mu') + \frac{2S^2}{N} \lambda \lambda' \} \quad (4.10)$$

Component or equivalent component data required in making reliability calculations, excluding outages due to maintenance and overloading, are the same as that listed previously for the exact Markov method.

Table(4.21) gives the results obtained by using the approximate method as compared with that obtained from Markov method. It is seen that the approximate method gives results that are within a few percent error as compared with those obtained by using the Markov method. It should be remarked that the Markov method itself is approximate and does depend upon certain specific distribution assumptions. It generates a series of linear equations which must be solved simultaneously to find the two lines properties such as failure rates and long run availability. If these two lines are not identical; eight simultaneous equations are required to be solved, and high speed digital computer must be used, while the approximate method requires only solving one approximate equation with explicit consideration of a 2-state

TABLE 4.21

NASRIYA -- SHUAIBA LINE.

NWOR = 0.501135/YEAR , SWOR = 173.733/YEAR

N = 650 (HR). S = 1.5 HR. EQ.OUT.RATE = 0.899/YEAR.

STORMY WEATHER FAILURES %	DURATION OF REPAIR (HR)	EQUIVALENT FAILURE RATE x 10^{-4}		MTTF	
		USING MARKOV TECH.	USING APP. METH.	USING MARKOV TECH.	USING APPROXIMATE METHOD
0	4.0	7.389	7.414	1.35[illegible]2	1.3487
	6.0	11.086	11.1214	0.9020	0.8991
	8.0	14.776	14.828	0.6767	0.6743
20	4.0	53.580	55.3109	0.1866	0.18074
	6.0	57.224	58.869	0.1747	0.16986
	8.0	60.855	62.428	0.16432	0.160182
40	4.0	185.153	199.000	0.05400	0.05025
	6.0	288.632	202.114	0.05500	0.04940
	8.0	192.100	205.229	0.0520	0.04872
60	4.0	392.43	438.48	0.0254	0.02280
	6.0	395.664	440.85	0.0252	0.02268
	8.0	398.885	443.229	0.02506	0.02256
80	4.0	666.931	773.76	0.01499	0.012923
	6.0	669.832	775.095	0.01492	0.012901
	8.0	672.729	776.930	0.01486	0.012879
100	4.0	1001.003	1204.83	0.00998	0.008299
	6.0	1003.53	1204.83	0.00964	0.008299
	8.0	1006.05	1204.83	0.00939	0.008299

fluctuating environments and used easily for different system configurations than that of Markov approach. But one of the great disadvantage of the approximate approach is the accumulation of error when evaluating the reliability indices of large networks due to successive approximation in each step of calculation.

For better comparison between the two methods see figs. (4.16-18).

4.6 The Effect of Line Mean Failure Rate And Mean Repair Rate on The Total MTTF and O.R For Two parallel Lines

As it has been shown previously that Markov technique is the most accurate method for determining the equivalent outage rates and reliability indices for different Configurations of transmission System. however, it is extremely laborious to attempt to obtain a general expression for the probability of accupying the failed states and for the system total MTTE. The following analyses shows the difficult and laborious expressions for these indices for two lines in parallel.

The matrix indicating transitional stochastic probabilitities given by Markov for two lines in parallel is

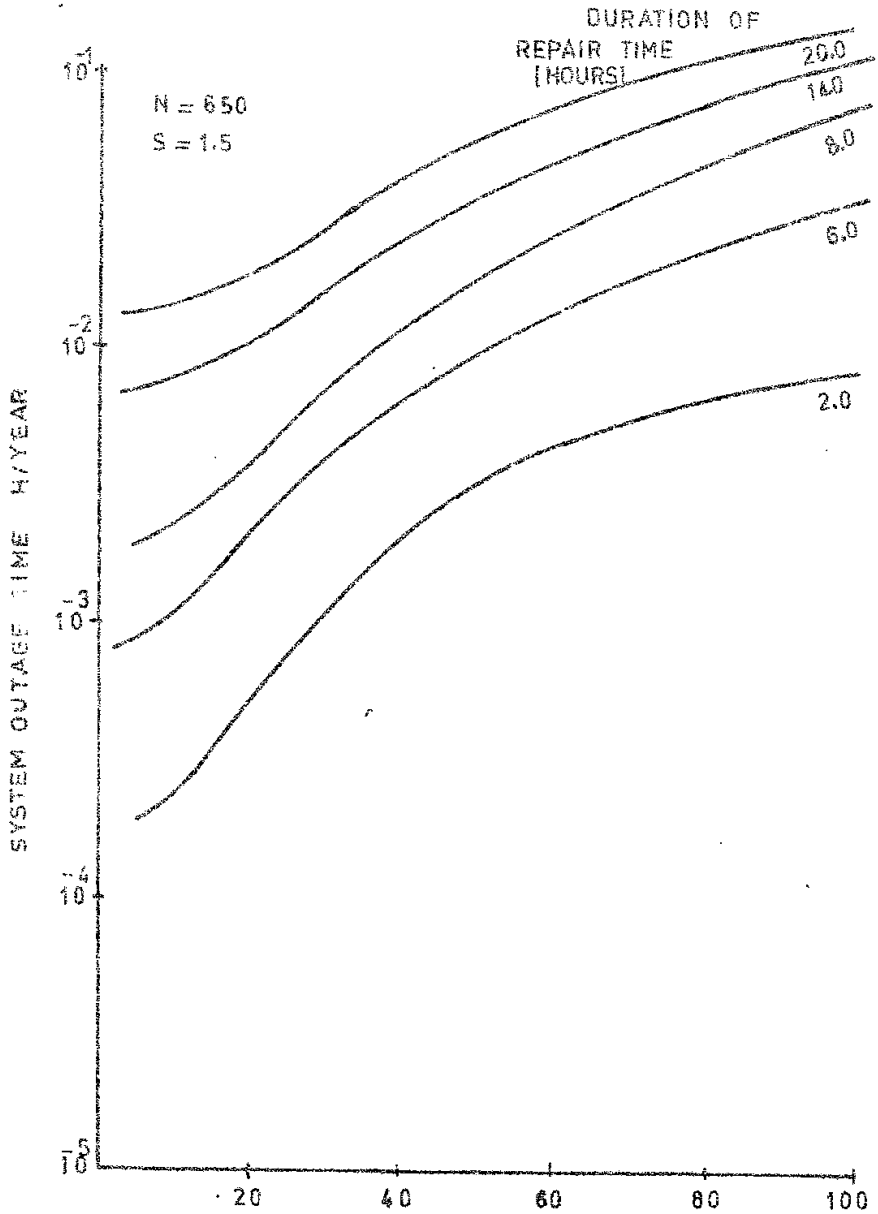


FIG.(4.16) OUTAGE TIME VARIATION WITH STORM ASSOCIATED FAILURE FOR NASSIRIYA – SHUAIBA LINE USING THE APPROXIMATE METHOD

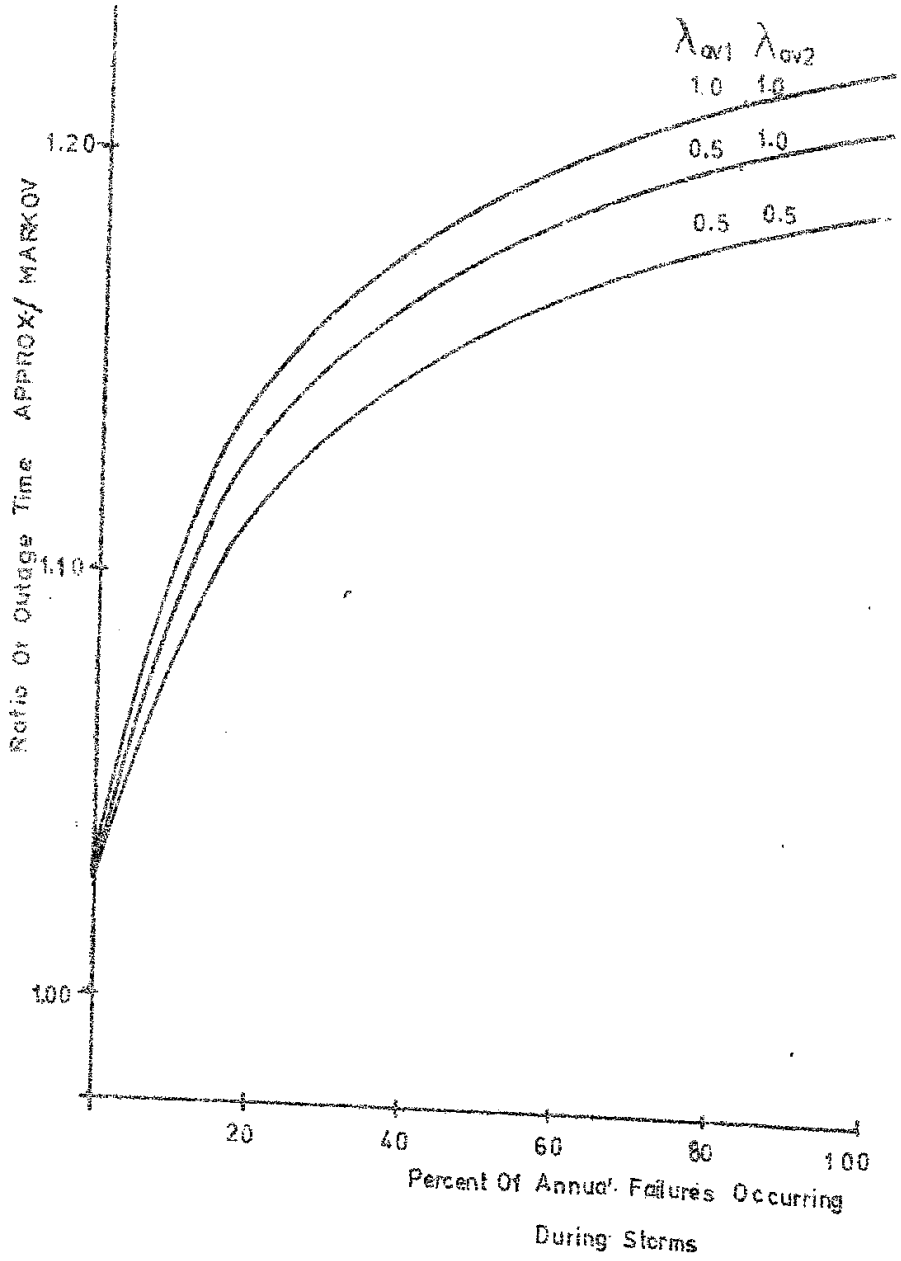


FIG.(4.17):COMPARISON OF SYSTEM OUTAGE TIME USING THE APPROXIMATE AND MARKOV METHODS FOR NASSIRIYA-SHUAIBA LINE . VARIABLE COMPONENT FAILURE RATE

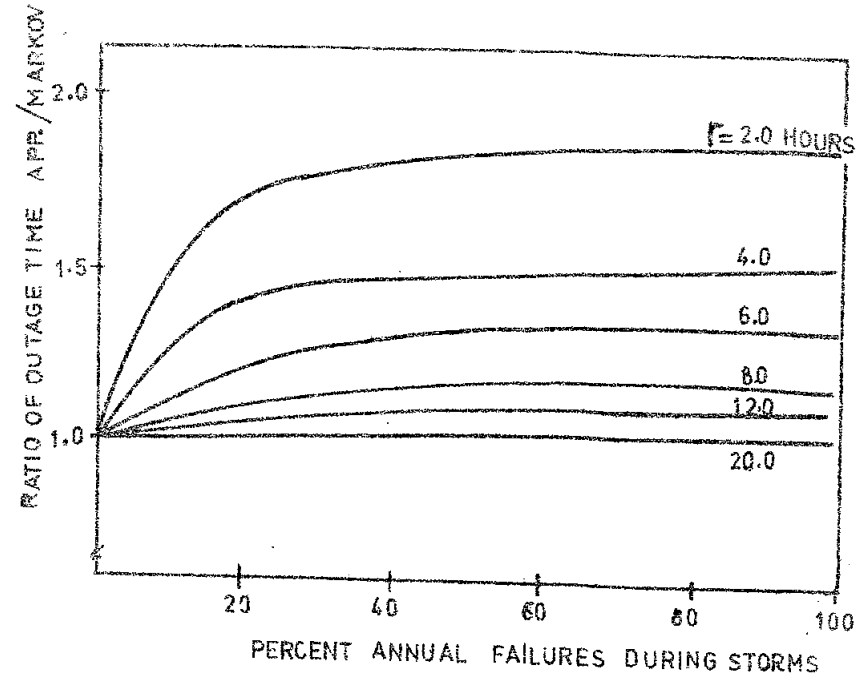


FIG.(4.18a):VARIABLE REPAIR TIME

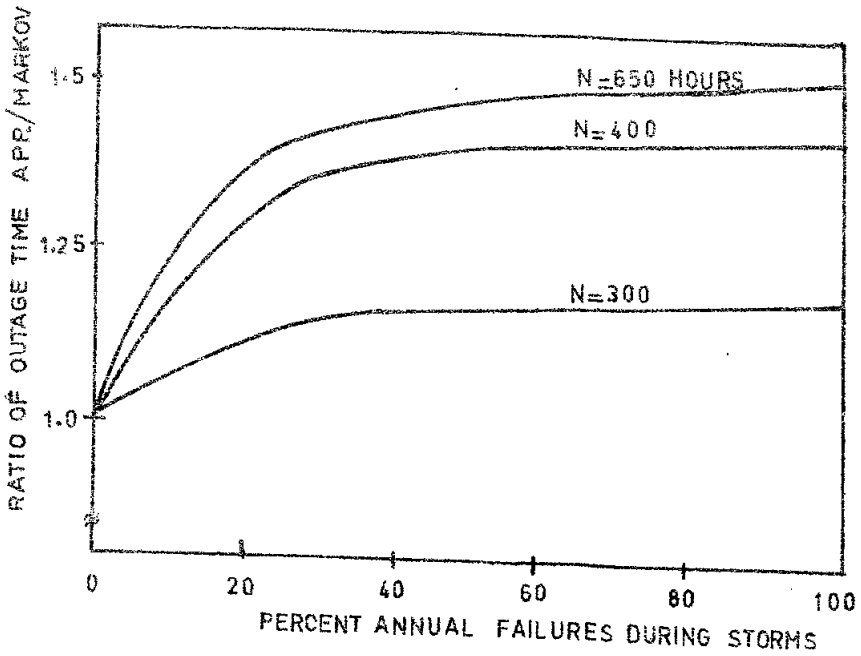


FIG.(4.18b)VARIABLE WEATHER DURATIONS

FIG(4.18):COMPARISON OF NASSIRIYA SHUAIBA OUTAGE TIME USING APPROXIMAT AND MARKOV METHODS

obtained by truncating the transitional Stochastic probability matrix given in eq. (3.36), by eliminating the observing states and then inverty the truncated matrix after subtructing the identiting matrix from it . Hence if the trancated matrix is $[Q]$ with (2) transitional states, then the general matrix $[B]$ is given by :

$$[I - Q] = - B = \begin{bmatrix} b_{11} & b_{12} & b_{13} \ldots . b_{12} \\ b_{21} & b_{22} & b_{23} \ldots . b_{22} \\ b.. & \ldots & \ldots \ldots \ldots \\ \ldots & \ldots & \ldots \ldots \ldots \\ b_{z1} & b_{z2} & b_{z3} \quad b_{z2} \end{bmatrix}$$

The inverse of this matrix gives a matrix $[C]$ (as given in eq. (3.43)), from this resulting matrix the MTTE starting from rth state is given by

$$M_r = - (C_{r1} + C_{r2} + C_{r3} + \ldots\ldots + C_{rz}) / |B|$$

where

$C_{r1}, C_{r2}, \ldots . C_{r2}$ are the Cofactors of $b_{r1}, b_{r2}, \ldots b_{r2}$ in the $[B]$ matrix.

The average failure rate starting from rth state is

$$\lambda_{avr} = 1 / M_r .$$

Now if the start is from state 0 i.e normal weather

$$\therefore \quad \lambda_{avo} = S_1 / S_0 \qquad \& \quad MTTF_0 = S_0 / S_1 .$$

where

$$S = [n\lambda'_1 + \lambda_1(\lambda'_1+m)]\ [n\lambda'_2 + \lambda_2(\lambda'_2+m)][(\lambda_1+\lambda_2)$$

$$(\lambda'_1+\lambda'_2+m)+n(\lambda'_1+\lambda_2)] + \mu_1(\lambda'_2+m)[n\lambda'_1$$

$$+\lambda_1(\lambda'_1+m)][\lambda_2(\lambda'_1+\lambda'_2+m)+n\lambda'_2] + \mu_2(\lambda_1+m)$$

$$[n\lambda'_2+\lambda_2(\lambda'_2+m)][\lambda_1(\lambda'_1+\lambda'_2+m)+n\lambda'_1] + n\lambda'_1\lambda'_2$$

$$\{\mu_2[n\lambda'_2+(\mu_1+\lambda_2)(\lambda'_2+m)] + \mu_1[n\lambda'_1+\lambda$$

$$(\lambda_1+\mu_2)(\lambda'_1+m)]\}$$

& $S_0 =$

$$[(\mu_1+\lambda_2)(\lambda'_2+m)+n\lambda'_2][\lambda_2(\lambda'_1+\lambda'_2+m)(n+\lambda'_1+m)$$

$$+n\lambda'_2(\lambda_1+\mu_2+m+n)] + [(\mu_2+\lambda_1)(\lambda'_1+m)+n\lambda'_1]$$

$$\{\lambda_1+\lambda'_2+m)[(\lambda'_2+m)(\mu_1+\lambda_2)+m\lambda_1+n(\lambda_1+\lambda'_2)+\lambda_1\lambda'_2]$$

$$+n(\lambda'_1+\lambda'_2)(\mu_1+\lambda_2+n)+mn(\lambda_1+\mu_1+\lambda_2)\}\ .$$

or $S = f(n, \lambda'_1, \lambda'_2, \mu_1, \mu_2, \lambda_1, \lambda_2, m)$.

$S_0 = g(n, \lambda_1, \lambda_2, \mu_1, \mu_2, \lambda'_1, \lambda'_2, m)$.

For two lines in parallel on the same towen

$$\lambda_1 \triangleq \lambda_2 = \lambda\ ,\quad \mu_1 \triangleq \mu_2,\ \lambda'_1 \triangleq \lambda'_2 = \lambda'\ .$$

if one keep all the parameters Constant except then:

$$S = a_1 \lambda^3 + a_2 \lambda^2 + a_3 \lambda + a_4 .$$

& $$S_o = e_1 \lambda^2 + e_2 \lambda + e_3$$

where a_1, a_2, a_3, a_4, e_1, e_2 and a_3 are Constants.

Hence

$$\lambda_{avo} = \frac{a_1 \lambda^3 + a_2 \lambda^2 + a_3 \lambda + a_4}{e_1 \lambda^2 + e_2 \lambda + e_3}$$

& $$MTTFO = \frac{e_1 \lambda^2 + e_2 \lambda + e_3}{a_1 \lambda^3 + a_2 \lambda^2 + a_3 \lambda + a_4}$$

However a digital computer programme is made to obtain a numerical solution to study the effect of variations of the individual parameter λ and μ for two parallel lines on the same tower i.e $\lambda_1 = \lambda_2$, $\mu_1 = \mu_2$ Considering two state fluctuating environment.

The stormy weather failure rate is maintained Constant and the mean time to failure and outage rate for the two lines are computed as a function of the M.F.R and the M.R.R of the single line the following studies are done.

a. λ is varied from 0.25-1.50 failure/year. keeping μ constant at r=6 Hours where $\mu = 1/r$.

b. r was varied from 2.0-12.0 Hours keeping λ constant at 0.5 failures/year.

c. λ and r is varied together from(0.25,2hr).to(1.5,12hr). The results are given in Table(4.22).

TABLE 4.22

The Mean Time To failure and total failure rate in South Region as a function of the Mean failure Rate (λ) and Mean Repair Rate (μ) of Single Tower double Circuit transmission line.

A. The Mean failure Rate is varied keeping the mean Repair Rate at 6.0 Rep/year.

(Failare/year)	P.U	MTTF x 10^{-2}	OUT.RATE.x10^{-3}
0.25	0.5	257.369	388.545
0.50	1.0	257.159	388.864
0.75	1.5	256.836	389.352
1.00	2.0	256.402	390.011
1.25	2.5	255.859	390.839
1.50	3.0	255.209	391.835

B. The Mean Repair Rate is varied Keeping the Mean Failure Rate at 0.50 Failure/year.

DURATION OF REPAIR

r(HOURS)	μ (P.U)	MTTF $x10^{-2}$	OUTAGE RATE $x10^{-3}$
2.0	0.5	257.364	388.553
4.0	1.0	257.261	388.708
6.0	1.5	257.159	388.864
8.0	2.0	257.056	389.019
10.0	2.5	256.954	389.174
12.0	3.0	256.851	389.329

C. Both the Mean Failure Rate and the mean Repair Rate are Varied

(λ , μ)Peryear	(λ , μ)P.U	MTTF $x10^{-2}$	OUTAGE RATE $x10^{-3}$
(0.25, r = 2)	0.5	257.435	388.447
(0.50, r = 4)	1.0	257.661	388.708
(0.75, r = 6)	1.5	256.836	389.359
(1.0 , r = 8)	2.0	256.050	390.547
(1.25, r =10)	2.5	254.805	392.459
(1.50, r =12)	3.0	253.004	395.249

4.7 Results and Conclusions

From studies made in this chapter, the following results and conclusions are reached.

a. The major causes of troubles and failures that Occur on Iraqi 132 K.V transmission system are due to insulator pollusions and meteorological phenomena.

b. The fluctuating environment in Iraq is found to have a great effect on the temporary and permanent outages of lines and equipments, and the distribution of the weather and failure durations are found to be exponential.

c. It is found that there are good correlations between the meteorolgical phenomena and the temporary failures that occur frequently on the transmission system facilities in this coucountry. Tables(4.7-10) give these correlations in a form of correlation coefficient as obtained by statistical test.

e. The system reliability measures are obtained considering the two-state weather variations. Table(4.13-17) give the results of the computer study of these measures.It is found, that Nassiriya-shuaiba line encounters many persisting failures during a year, while kirkuk-sulaimanya encounters many tempory failures during a year.

f. The Markov exact method is easy to apply for relatively small system configurations and provide most accurate result than any other existing technique.

g. The frequency and duration (approximate)method provide a reasonable and satisfactory results for simple network configurations when considering the two-state fluctuating environment.

h. The effect of variations of the failure rate for the individual lines in a double circuit parallel transmission line carried on single tower on the total system mean time to failure are negligable.

i. Generally, for two parallel lines, the mean time to failure of the system is more sensitive to the variation of the repairing time during low storm weather period, while for high storm periods, the effect of repairing time is negligable.

j. It is very difficult to obtain a general expression for the MTTF and outage rates of the total system using Markov technique even for simple system configuration as indicated in section (4.6).

PART - III

DISTRIBUTION SYSTEM RELIABILITY EVALUATION

CHAPTER 5

5.1 Introduction

In modern electric power supply networks the service reliability factor becomes an important condition to be satisfied. So an increasing amount of attention is being focused on this factor for distribution systems. This increased attention primarily stems from the following two points:

a. The need to supply improved service as constomers become more dependant on their electric service.

b. The desire to design new system in order to supply the heavier loads of the future.

Methods of probability theory and theory of sets provide a good tool for the evaluation of distribution system reliability.

The work presented in this chapter will introduce the basic concept of reliability for different system configurations. The method is then extended to find a general formula for solving the ring-bus system with any number of feeders.

This method is also applied for different practical schemes such as double bus-bar double breaker, and breaker and a half scheme as two practical switchgear arrangements mainly used in supply distribution and in some high voltage schemes.

5.2 Theory of Probability

If P(A) is the probability that an event A will occur, and P(A or B) the probability that event A or event B will occur, then : -

$$P(A+B) = P(A \cup B) = P(A \text{ or } B)$$
$$= P(A) + P(B) - P(A).P(B) \quad \ldots\ldots(5.1)$$

If A and B are mutually exclusive events, then

$$P(A+B) = P(A \cup B) = P(A \text{ or } B)$$
$$= P(A) + P(B) \quad \ldots\ldots(5.2)$$

As an extention of equations (5.1) and (5.2) for N events, thus : -

$$P(A+B+ \ldots\ldots + N)$$
$$= P(A) + P(B) + \ldots\ldots + P(N)$$
$$- \{ P(AB) + P(AC) + \ldots\ldots + P(MN) \}$$
$$+ \{ P(ABC) + P(ABD) + \ldots\ldots + P(LMN) \}$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$+ P\{ A.B.C\ldots\ldots N \} \quad \ldots\ldots(5.3)$$

If A, B, ..., N are mutually exclusive events, then

$$P(A + B + \ldots\ldots + N) = P(A) + P(B) + \ldots + P(N)$$
$$\ldots\ldots(5.4)$$

If P(L and K) is the probability that events L and K will occur, and P(L/K) the probability that event L will occur if event K has occurred, or the conditional

$$P(K.L) = P(K \cap L) = P(K \text{ and } L)$$

$$= P(K).P(L/K) \qquad \ldots\ldots(5.5)$$

If K and L are independent events, then:-

$$P(KL) = P(K).P(L) \qquad \ldots\ldots(5.6)$$

Extending equations (5.5) and (5.6) for the case of N events, thus:-

$$P(ABC \ldots N) = P(A).P(B/A) \ldots P(N/AB \ldots M) \ldots(5.7)$$

If A,B, ... N are independent events, then : -

$$P(AB \ldots N) = P(A).P(B) \ldots\ldots P(N) \qquad \ldots\ldots(5.8)$$

5.3 Reliability of Assemblies [24]

The system available here will consist of elements A,B, ...,N. The elements can operate successfully with probabilities $P_a, P_b, \ldots P_n$ or fail to operate with probabilities $Q_a, Q_b, \ldots Q_n$. The failures are assumed to be random and independent. The successful and failed states of an ith element will be denoted by P_i and Q_i respectively. The probabilities of system success and failure s will be written as I and Q, when time effects are not concerned, and R(t) will denote probability of success during a stated period of duration , i.e reliability for time t.

5.1 Series Reliability

Figure(5.1) represents the simplest reliability configuration. Each element must be satisfactory for the system to succeed.

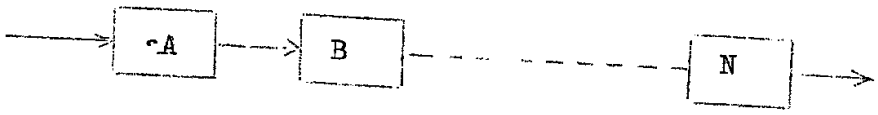


Fig.(5.1)

Series Reliability Configuration

The probability of success is : -

$$P = P_a . P_b \ldots P_n = \prod_{i=1}^{n} P_i$$

$$= \prod_{i=1}^{n} (1 - Q_i) \qquad \ldots\ldots(5.9)$$

$$= 1 - \sum_{i=1}^{n} Q_i \quad \text{if } Q_i \ll 1 \ldots\ldots(5.10)$$

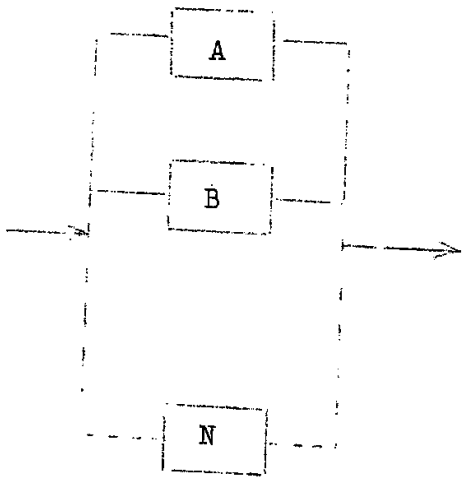
If the distribution of the time of success of a a system is required, it is usual to assume that the elements have a constant time failure rate.

P_i becomes $e^{-\lambda_i t}$ where λ_i being the failure rate of i - th element and t the period over which time reliability is calculated. For a series system with n elements, reliability R(t) is given by :

$$R(t) = \exp\left(-\sum_{i=1}^{n} \lambda_i t\right) \qquad \ldots\ldots(5.11)$$

5.3.2 Parallel Reliability

For the parallel configuration, shown in Fig.(5.2) the system fails if all the elements fail, i.e.



Figure(5.2)
Parallel reliability
Configuration

$$Q_T = \prod_{i=1}^{n} Q_i = \prod_{i=1}^{n} (1 - P_i) \qquad \ldots\ldots(5.12)$$

The system operation is given by : -

$$P = 1 - \prod_{i=1}^{n} Q_i \qquad \ldots\ldots(5.13)$$

when time effect are considered, thus equation(5.13) reduces to the following form : -

$$R(t) = 1 - \prod_{i=1}^{n} (1 - \exp(-\lambda_i t) \qquad \ldots\ldots(5.14)$$

5.4 General Approach of Circuit Configurations (25)

In the following discussion different system configurations will be analysed from the reliability point of view and a general approach for solution of these configurations is developed

5.4.1 Two Elements Network

a. Network of two series elements: consider a network consisting of two elements "A" and "B" connected in series, as shown in fig. (5.30)

The network is available if both elements A and B are available, hence the probability of which is given by :-

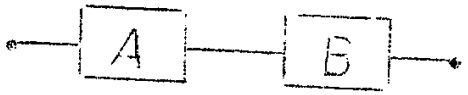


Fig.(5.3a)
Two elements in series

$$P(A \cap B) = P_a P_b = P_{series} \quad \ldots\ldots(5.15)$$

The resultant network is unavailable that is withen A or B or both.

$$P(\bar{A} \cup \bar{B}) = Q_a + Q_b - Q_a Q_b = Q_{series} \quad \ldots\ldots(5.16)$$

b. Two parallel element network: Fig.(5.3b) shows a network of two elements A and C connected in parallel. The network is available if either A or C or both , are available, this can be represented by $P(A \cup C)$, thus the

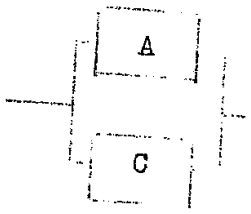


Fig.(5.3b)
Two element A
and C in parallel

$$P(A \cup C) = P_a + P_c - P_a \cdot P_c \quad \ldots\ldots(5.17)$$

and $$= P_{parallel}$$

$$P(\bar{A} \cap \bar{C}) = Q_{parallel} = Q_a \cdot Q_c \quad \ldots\ldots(5.18)$$

5.4.2 Three Elements Networks

Consider the case of three elements network built up of series and parallel elements condition as shown in fig. (5.4 a), then the resultant network is available if (A or C, and B) or (A and B and C) are available the probabilistic representation : -

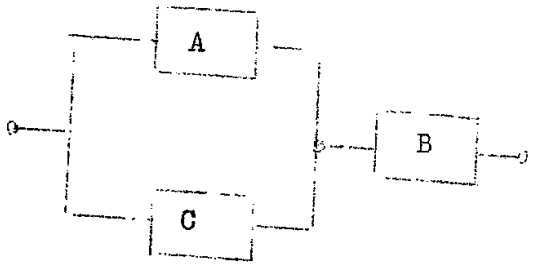


Fig.(5.4 a)
Three element
Network type(a)
of availability is

$$P\left[(A \cup C) \cap B\right] = P\left[(A \cap B) \cup (C \cap B)\right]$$

$$= P_a P_b + P_c P_b - P_a P_b P_c \quad \ldots(5.19)$$

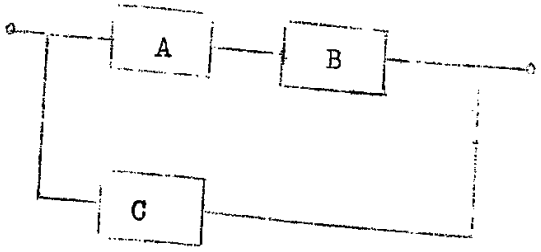
and Unavailability

$$P\left[\overline{(A \cup C) \cap B}\right] = 1 - (P_a P_b + P_c P_b - P_a P_b P_c)$$

$$= 1 - P_a P_b - P_c P_b + P_a P_b P_c$$

Now if the same elements are connected in other arrangement as shown in fig. (5.4 b) then the resultant network is available if (C or, A and B) or (A and B and C) are available then the probabilistic representation is given by:-

Fig. (5. 4 b)



Availability

$$P\left[(A \cap B) \cup C\right] = P_a P_b + P_c - P_a P_b P_c \quad \ldots.(5121)$$

Unavailability

$$P\left[\overline{(A \cap B) \cup C}\right] = 1 - P_a P_b - P_c + P_a P_b P_c \quad \ldots(5.22)$$

5.4.3 Four Elements Networks

Fig.(5.5 a,b) presents two type of four element networks.

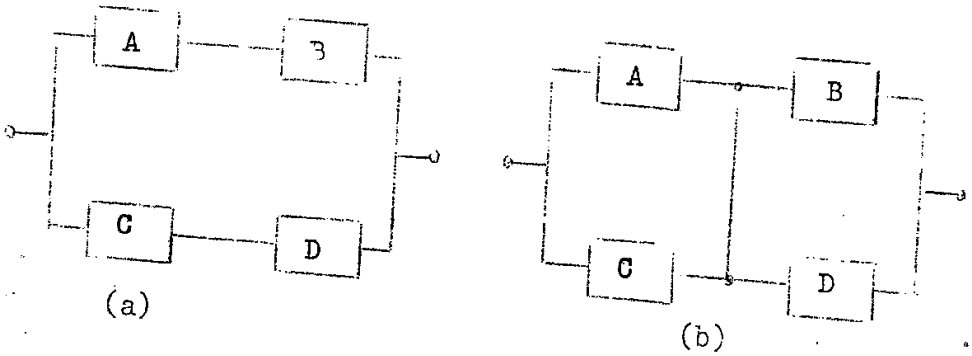


Fig.(5.5)

Four element networks.

Consider now the network given in fig.(5.5 a), the network is available if element (A and B or C and D) on (A and B and D and C) are available. The resultant availability is given by the probability equation as follows:-

Availability

$$P\left[(A\cap B)\cup(C\cap D)\right] = P_aP_b+P_cP_d-P_aP_bP_cP_d \quad \ldots(5.23)$$

Unavailability

$$P\left[\overline{(A\cap B)\cup(C\cap D)}\right] = 1-P_aP_b-P_cP_d+P_aP_bP_cP_d \ldots(5.24)$$

Now for fig.(5.5 b), the network is available if (A and B or C and D) or (C and B or A and D) are available. There fore the resultant availability and unavailability of the network is given by: -

Availability

$$P\left[(A\cup C)\cap(B\cup D)\right] = (P_a+P_c-P_aP_c)\cdot(P_d+P_b-P_dP_b)$$

$$= P_aP_b+P_aP_d-P_aP_bP_d+P_cP_d+P_cP_b$$

$$-P_cP_bP_d-P_dP_aP_c-P_bP_aP_c+P_aP_bP_cP_d$$

$$\ldots.(5.25)$$

and Unavailability

$$P\left[\overline{(A\cup C)\cap(B\cup D)}\right] = 1-P_aP_b-P_aP_d+P_aP_bP_d-P_cP_d-P_cP_b$$

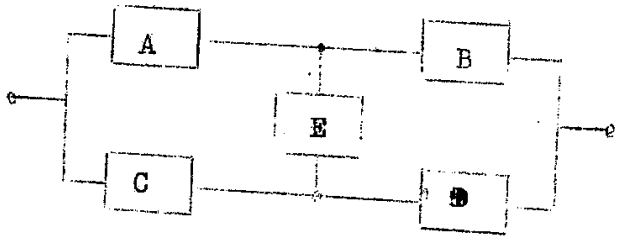
$$+P_cP_bP_d+P_dP_aP_c+P_aP_bP_c-P_aP_bP_cP_d$$

$$\ldots\ldots(5.26)$$

5.4.4 Bridge Circuit

Consider now the bridge circuit shown in Fig.(5.6) with five arms passing through elements A, B, C, D and E.

The network is available if at least one path along which all elements are available. The possible paths in this bridge network are as follows:



Fig(5.6)
Bridge Circuit Network

Path 1 through $(A \cap B)$

Path 2 through $(C \cap D)$

Path 3 through $(A \cap E \cap D)$

Path 4 through $(C \cap E \cap B)$

The network is available, if one or more of the above paths are available, and this is given by :

$$(A \cap B) \cup (C \cap D) \cup (A \cap E \cap D) \cup (C \cap E \cap B)$$

The probability of this condition is : -

$$P_{bridge} = P(A \cap B) + P(C \cap D) + P(A \cap E \cap D) + P(C \cap E \cap B)$$
$$- P(A \cap B \cap C \cap D) - P(C \cap D \cap A \cap E \cap D)$$
$$- P(A \cap E \cap D \cap C \cap E \cap B) - P(C \cap E \cap B \cap A \cap B)$$
$$- P(C \cap E \cap B \cap C \cap D) - P(C \cap B \cap C \cap E \cap B)$$
$$+ P(A \cap B \cap C \cap D \cap A \cap E \cap D)$$

$$+ P(C \cap D \cap A \cap E \cap D \cap C \cap E \cap B)$$

$$+ P(A \cap E \cap D \cap C \cap E \cap B \cap A \cap B)$$

$$+ P(C \cap E \cap B \cap A \cap B \cap C \cap D)$$

$$- P(A \cap B \cap C \cap D \cap A \cap E \cap D \cap C \cap E \cap B)$$

or

$$P_{bridge} =$$

$$P_aP_b+P_cP_d-P_aP_dP_e+P_bP_cP_e-P_aP_bP_cP_d-P_aP_bP_cP_e$$

$$-P_aP_cP_dP_e-P_aP_bP_dP_e-P_bP_cP_dP_e+2P_aP_bP_cP_dP_e \quad \ldots\ldots(5.27)$$

It can be shown that Eq.(5.27) used as a general solution for all above network configurations by substituting (1) and (0) for short and open paths respectively. The following table shows how the previous equations can be obtained from the reliability formula of the bridge circuit, Eq.(5.27), as a general solution.

Table (5.1)

General Solution For Different Network Configurations Using Bridge Circuit Reliability Formula.

Network Configuration	A	B	C	D	E	Resultant formula obtained from bridge circuit Eq.
A & B in Series	✓	✓	0	0	0	$P_a P_b$
C & D in Series	0	0	✓	✓	0	$P_c P_d$
A &C in Parallel	✓	1	✓	1	0	$P_a+P_c - P_a P_c$
(A//C) in Series with B	✓	✓	✓	0	1	$P_a P_b + P_c P_b - P_a P_b P_c$
(A & B in Series) //C	✓	✓	✓	1	0	$P_a P_b + P_c - P_a P_b P_c$
(A & B in Series) //(C & D in Series)	✓	✓	✓	✓	0	$P_a P_b + P_c P_d - P_a P_b P_c P_d$
(A// C) in Series) with (B// D)	✓	✓	✓	✓	1	$P_a P_b + P_a P_d - P_a P_b P_d - P_c P_d$ $+P_c P_b - P_c P_d P_b - P_d P_a P_c$ $-P_a P_b P_c + P_a P_b P_c P_d$.

5.5 Practical Power Supply Schemes(26),(27)

Reliability of practical schemes can always be improved at the expense of cost and size.

The addition of extra paths proves to increase the continuity of supply. This is really where redundency steps in, with its two techniques: components redundenoy and units redundency. This approach is dealt with in the practical schemes of power supply as follows:-

5.5.1 Single Bus-Bar Scheme (System I)

The simplest and cheapest type of practical Switch-gear connection is the single bus-bar scheme which consist of two isolators A & C, and one circuit breaker B. This scheme (SystemI) is shown in Fig.(5.7). The resultant system is available if the three elements are simultaneously in ope- ration states, thus:

$$P_I = P(A \cap B \cap C) = P_a P_b P_c \quad \ldots\ldots(5.28)$$

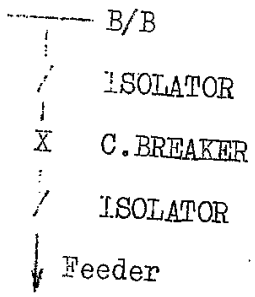


Fig.(5.7)Single B/B Scheme

The unavailability of this scheme can take the following form :

$$Q_I = 1 - P_I = 1 - P_a P_b P_c$$

$$= 1 - (1 - Q_a)(1 - Q_b)(1 - Q_c)$$

$$= Q_a + Q_b + Q_c - Q_a Q_b - Q_a Q_c - Q_c Q_a + Q_a Q_b Q_c$$

.....(5.29)

If the two isolators A and C are identical, then

$P_a = P_c$ and $Q_a = Q_c$

$$P_I = P_a^2 P_b \qquad .....(5.30)$$

and

$$Q_I = 2Q_a + Q_b - Q_a^2 - 2Q_a Q_b + Q_a^2 Q_b \quad .... (5.31).$$

The yearly failure time of this system may be given by the following formula : -

$$T_{fI} = 8760 (1 - P_I) \quad \text{Hours}$$

$$= 8760\, Q_I \qquad .....(5.32)$$

Table I shows the system reliability for different values of isolator and circuit breaker reliabilities.

Table 5.2

Parameters of System I

$R_a=R_b=R_c$	System Reliability P_I	Yearly Expected Outage time
0.9000	0.729000	2374.000
0.9900	0.970294	260 .180
0.9990	0.997002	26.264
0.9999	0.999700	2.628

5.5.2 Double Bus-Bar Double Breaker Systems(System II):

The single bus-bar layout does not allow for breaker or isolator maintenance without outage of supply. In order to over come this difficulty, double bus-bar double breaker schemes are used. Consequentely, this scheme is expensive, and it is only used for very large generating plants where security of connection is paramount.

Fig.(5.8) shows the layout of this scheme(system II), where the system is available if at least one of the parallel paths A,B,C, or $A_2B_2C_2$ is available. This can be obtained as follows: -

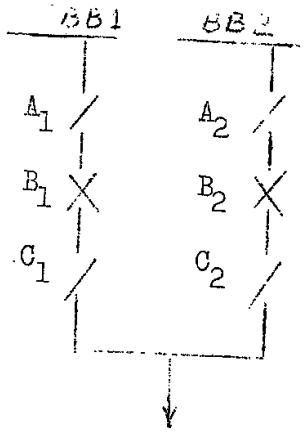


Fig.(5.8)

$$P_{II} = P\left[(A_1 \cap B_1 \cap C_1) \cup (A_2 \cap B_2 \cap C_2)\right]$$

$$= P(A_1 \cap B_1 \cap C_1) + P(A_2 \cap B_2 \cap C_2) - P(A_1 \cap B_1 \cap C_1 \cap A_2 \cap B_2 \cap C_2)$$

$$= P_{a1}P_{b1}P_{c1} + P_{a2}P_{b2}P_{c2} - P_{a1}P_{b1}P_{c1}P_{a2}P_{b2}P_{c2} \quad \ldots\ldots\ldots(5.33)$$

The unavailability of this system is given by :-

$$Q_{II} = 1 - P_{II} = 1 + P_{a1}P_{b1}P_{c1}P_{a2}P_{b2}P_{c2} - P_{a1}P_{b1}P_{c1} - P_{a2}P_{b2}P_{c2} \quad \ldots(5.34)$$

5.5.3 Double Bus-Bar with Breaker and a Half Scheme:

This system is a compromise between the two previous systems. It proves to be the most reliable as well as economical arrangement for feeding two feeders in a ring system. Fig(5.9) shows the layout of this system(system III).

The reliability of the feeders can take the following forms:

$$P_{III} = P\left[(A_1 \cap B_1 \cap C_1) \cup (A_2 \cap B_2 \cap C_2 \cap A_3 \cap B_3 \cap C_3) \right]$$

$$= P(A_1 \cap B_1 \cap C_1) + P(A_2 \cap B_2 \cap C_2 \cap A_3 \cap B_3 \cap C_3) - P(A_1 \cap B_1 \cap C_1)\, P(A_2 \cap B_2 \cap C_2 \cap A_3 \cap B_3 \cap C_3)$$

$$= P_{a1}P_{b1}P_{c1} + P_{a2}P_{b2}P_{c2}P_{a3}P_{c3} - P_{a1}P_{b1}P_{c1}P_{a2}P_{b2}P_{c2}P_{a3}P_{b3}P_{c3} \quad \ldots\ldots(5.37)$$

The failure rate of the sytem is given by

$$\varphi_{III} = 1 - P_{III}$$

$$= 1 + P_{a1}P_{b1}P_{c1}P_{a2}P_{b2}P_{c2}P_{a3}P_{b3}P_{c3} - P_{a1}P_{b1}P_{c1} - P_{a2}P_{b2}P_{c2}P_{a3}P_{b3}P_{c3} \quad \ldots\ldots(5.38)$$

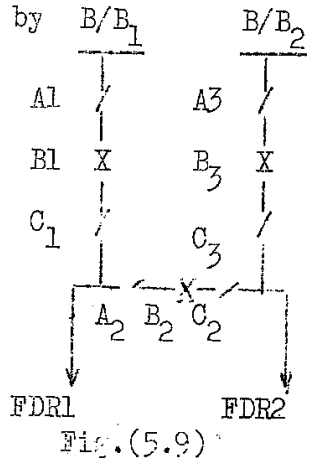


Fig.(5.9)

Breaker and a half Scheme.

If $P_{a1} = P_{a2} = P_{a3} = P_{c1} = P_{c2} = P_{c3} = P_a$

and $P_{b1} = P_{b2} = P_{b3} = P_b$, thus : -

$$P_{III} = P_a^2 P_b + P_a^4 P_b^2 - P_a^6 P_b^3$$

$$= P_I + P_I^2 - P_I^3 \qquad \ldots\ldots(5.39)$$

$$Q_{III} = 1 - P_{III} = (1 - P_I)(1 - P_I^2)$$

The yearly failure time is given by : -

$$T_{fIII} = 8760 (1 - P_{III})$$

$$= 8760 (1 + P_I^3 - P_I - P_I^2) \qquad \ldots\ldots(5.40)$$

$$= 8760 (1 - P_I)(1 - P_I^2)$$

The following table shows the reliability and failure time/year for different values of elements reliability:

Table (5.4)

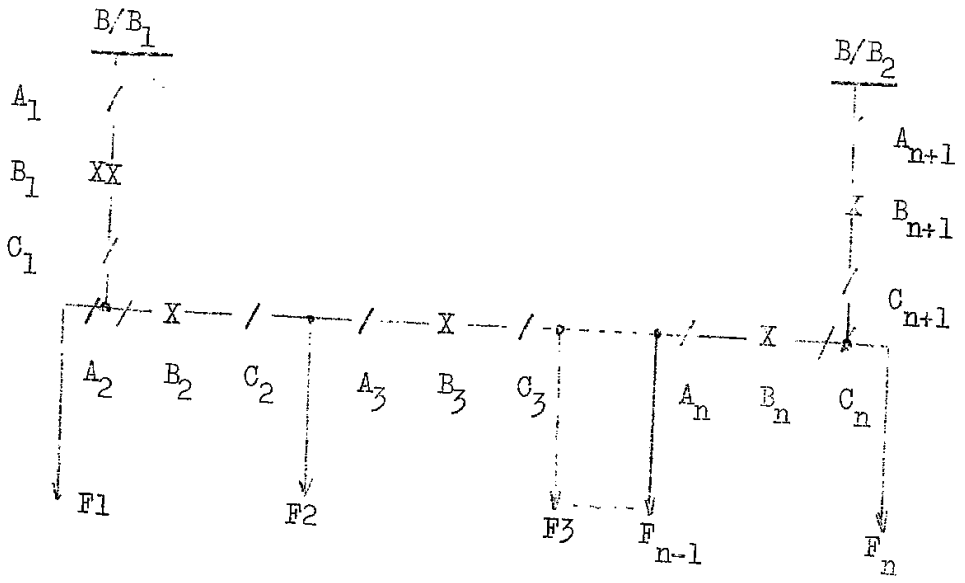
System Parameters For Breaker and a Half Scheme

$P_a = P_b = P_c$	P_{III}	T_{fIII}
0.9000	0.873020	1112.342
0.9900	0.998261	15.22759
0.9990	0.999982	0.158729
0.9999	0.999999	0.004177

5.6 General Solution of Ring Schemes

The ring bus-bar scheme has the appearance of possessing almost all the desirable features. As the ring is closed each feeder has two sources of supply, and any circuit breaker may be taken out of service without affecting the supply. If, however a second breaker opens, a number of circuits will be lost, and for this reason the ring scheme should be limited to four or six circuits.

Consider the ring scheme as shown in fig. (5.10)



Fig(5.10) = Ring Bus-Bar Schem With (n) out going feeders

The availability of feeder 1 is given by : -

$$P_{F1}=P\left[(A_1\cap B_1\cap C_1)\cup(A_2\cap B_2\cap C_2\cap \ldots\ldots\cap A_{n+1}\cap B_{n+1}\cap C_{n+1})\right]$$

$$=P(A_1\cap B_1\cap C_1)+P(A_2\cap B_2\cap C_2\cap \ldots\ldots\cap A_{n+1}\cap B_{n+1}\cap C_{n+1})$$

$$-P(A_1\cap B_1\cap C_1\cap A_2\cap B_2\cap C_2\cap \ldots\ldots\cap A_{n+1}\cap B_{n+1}\cap C_{n+1})$$

$$= P_{a1}P_{b1}P_{c1}+P_{a2}P_{b2}P_{c2}\cdots P_{a(n+1)}P_{b(n+1)}P_{c(n+1)}$$

$$-P_{a1}P_{b1}P_{c1}P_{a2}P_{b2}P_{c2}\cdots P_{a(n+1)}P_{b(n+1)}P_{c(n+1)}.$$

If $P_{a1} = P_{a2} = P_{a3} = \ldots\ldots = P_{a(n+1)} = P_a$

$P_{b1} = P_{b2} = P_{b3} = \ldots\ldots = P_{b(n+1)} = P_b$

$P_{c1} = P_{c2} = P_{c3} = \ldots\ldots = P_{c(n+1)} = P_c$

and since for single bus-bar scheme (system 1)

$P_I = P_2^2 P_b$

then

$$P_{F1} = P_I + P_I^n - P_I^{n+1} \qquad \ldots\ldots(5.41)$$

or

$$Q_{F_1} = (1 - P_I)\ (1 - P_I^n\ )$$

Also the availability of feeder 2 is : -

$$P_{F2}=P\Big[(A_1\cap B_1\cap C_1\cap A_2\cap B_2\cap C_2)\cup(A_3\cap B_3\cap C_3\cap \ldots$$

$$\cap A_{n+1}\cap B_{n+1}\cap C_{n+1})\Big]$$

$$=P(A_1\cap B_1\cap C_1\cap A_2\cap B_2\cap C_2)+P(A_3\cap B_3\cap C_3\cap \ldots$$

$$\cap A_{n+1}\cap B_{n+1}\cap C_{n+1})$$

$$-P(A_1\cap B_1\cap C_1\cap A_2\cap B_2\cap C_2\cap A_3\cap B_3\cap C_3\cap \ldots$$

$$\cap A_{n+1}\cap B_{n+1}\cap C_{n+1}).$$

$$= P_{a1}P_{b1}P_{c1}P_{a2}P_{b2}P_{c2} + P_{a3}P_{b3}P_{c3} \cdots P_{an+1}P_{bn+1}P_{cn+1}$$

$$- P_{a1}P_{b1}P_{c1}P_{a2}P_{b2}P_{c2}P_{a3}P_{b3}P_{c3} \cdots P_{an+1}P_{bn+1}P_{cn+1} .$$

and Similarly :

$$P_{F2} = P_I^2 + P_I^{n+1-2} - P_I^{n+1}$$

$$= P_I^2 + P_I^{n-1} - P_I^{n+1} \quad \Big\} \ldots\ldots (5.42)$$

$$Q_{F2} = (1 - P_I^2)(1 - P^{n-1})$$

Now for any feeder in the ring system (k) :

$$P_{Fk} = P\ (A_1 \cap B_1 \cap C_1 \cap A_2 \cap B_2 \cap C_2 \cap \ldots \cap A_k \cap B_k \cap C_k) \cup$$

$$(A_{k+1} \cap B_{k+1} \cap C_{k+1} \cap \ldots \cap A_{n+1} \cap B_{n+1} \cap C_{n+1}) .$$

$$= P(A_1 \cap B_1 \cap C_1 \cap A_2 \cap B_2 \cap C_2 \cap \ldots \cap A_k \cap B_k \cap C_k)$$

$$+ P(A_{k+1} \cap B_{k+1} \cap C_{k+1} \cap \ldots \cap A_{n+1} \cap B_{n+1} \cap C_{n+1})$$

$$- P(A_1 \cap B_1 \cap C_1 \cap A_2 \cap B_2 \cap C_2 \cap \ldots \cap A_k \cap B_k \cap C_k \cap \ldots$$

$$\cap A_{n+1} \cap B_{n+1} \cap C_{n+1}) .$$

$$= P_{a1}P_{b1}P_{c1}P_{a2}P_{b2}P_{c2} \cdots P_{ak}P_{bk}P_{ck}$$

$$+ P_{ak+1}P_{bk+1}P_{ck+1} \cdots P_{an+1}P_{bn+1}P_{cn+1}$$

$$- P_{a1}P_{b1}P_{c1}P_{a2}P_{b2}P_{c2} \cdots P_{ak}P_{bk}P_{ck} \cdot P_{ak+1}P_{bk+1}P_{ck+1}$$

$$\ldots P_{an+1}P_{bn+1}P_{cn+1} .$$

Using the same assumptions as in the above equation (5.41,42) the reliability of k-th feeder in a ring system is given by : -

$$P_{Fk} = P_I^k + P_I^{n+1-k} - P_I^{n+1}$$

$$Q_{Fk} = (1 - P_I^k)\ (\ 1 - P_I^{n+1-k}\ )$$

or in general the reliability of any feeder can be obtained from the following ring-bus general formula :

$$\boxed{P_i = P_I^i + P_I^{n+1-i} - R^{n+1}} \qquad \ldots\ldots(5.42)$$

and the unavailability is given by :

$$Q_i = 1 - P_i = 1 + P_I^{n+1} - P_I^{n+1-i} - P_I^i \qquad \ldots(5.43)$$

$$Q_i = 1 - P_i = (1 - P_I^i)\ (\ 1 - P_I^{n+1-i}\ )$$

and the yearly expected outage time in hours for any feeder in the ring system is given by :

$$T_{fi} = 8760(1-P_i)$$

$$= 8760(1+P_I^{n+1} - P_I^i)(1-P_I^{n+1-i}) \qquad \ldots\ldots(5.44)$$

These equations are programmed and worked on the IBM 1130 digital computer in order to study the availability characteristics for each feeder in the ring system when the number of the feeders is varied. The results are given in tables(5.5,6.7). The effect of variations of the number of feeders in the system on the availabilities of

the individual feeders is shown in fig(5.11,15)It is noticed that the reliability of each feeder is improved by decreasing the number of the outgoing feeders, and also the most reliable feeders are those which are near the feeding points.

5.7 Practical Applications of the General Ring-Bus Formula

The general ring-bus formula is now applied to a different practical power supply schemes in order to find the availabilities, unavailabilites and outage times for the individual system feeders. The application of this formula for these schemes is done by replacing (n) in the formula by its actual number which represents the number of feeders supplying loads in the scheme, this may be done as follows: -

a. Double Bus-Bar Double Breaker Schemes(System II).

The general ring-bus formula can be applied directly to the double bus-bar double breaker scheme which has been discussed in subsection (5.4.2), by replacing i=1 and n=1 Since this scheme has only one outgoing feeder this yield:

$$n = 1$$

$$i = 1$$

Table (5.5) Variation of The Individual Feeders Availability of a Ring System with The Elements Availabilities(Three Feeders System)

Element Reliability	FDR No.1		FDR No.2		FDR No.3	
	P_1	Tf_1	P_2	Tf_2	P_3	Tf_3
0.9000	0.833990	1454.241	0.780452	1923.239	0.833990	1454.241
0.9900	0.997431	22.503	0.996575	30.000	0.997431	22.503
0.9990	0.999973	0.237050	0.999964	0.314326	0.999973	0.237050
0.9999	0.999999	0.002088	0.999999	0.004177	0.999999	0.002088

Table (5.6) Variation of The Individual Feeders Availabilities of a Ring System with the Elements Availabilities. (4 Feeders System).

Element Reliability	FDR No.1		FDR No.2		FDR No.3		FDR No.4	
	P1	Tf_1	P2	Tf_2	P3	Tf_3	P4	Tf_4
0.9000	0.80538	1703.485	0.712970	2514.382	0.712270	2514.382	0.805538	1703.485
0.9900	0.996625	29.562	0.994930	44.336	0.994933	44.336	0.996625	29.562
0.9990	0.999969	0.314326	0.999946	0.470967	0.999946	0.470967	0.999964	0.314326
0.9999	0.999999	0.00417	0.999999	0.006265	0.999999	0.006265	0.999999	0.00417

	OUTAGE TIME IN HOURS/YEAR						
n	Feeder 1 (1-R(1)) x 8760	Feeder 2 (1-R(2)) x 8760	Feeder 3 (1-R(3)) x 8760	Feeder 4 (1-r(4)) x 8760	Feeder 5 (1-R(5)) x 8760	Feeder 6 (1-R(6)) x 8760	Feeder 7 (1-R(7)) x 8760
1	7.72866	...	...	...	...	...	...
2	15.227	15.227	...	...	...	...	...
3	22.503	30.000	22.503	...	...	...	...
4	29.562	44.336	44.336	29.562	...	...	...
5	36.413	58.245	65.521	58.243	36.413	...	...
6	43.057	71.74	86.0773	86.0773	71.74	43.057	...
7	49.507	84.837	106.024	113.081	106.024	84.837	49.507

TABLE(5.7) VARIATION OF FEEDER RELIABILITY WITH THE NUMBER OF FEEDERS FOR A RING SYSTEM ELEMENTS RELIABILITY = 0.990000

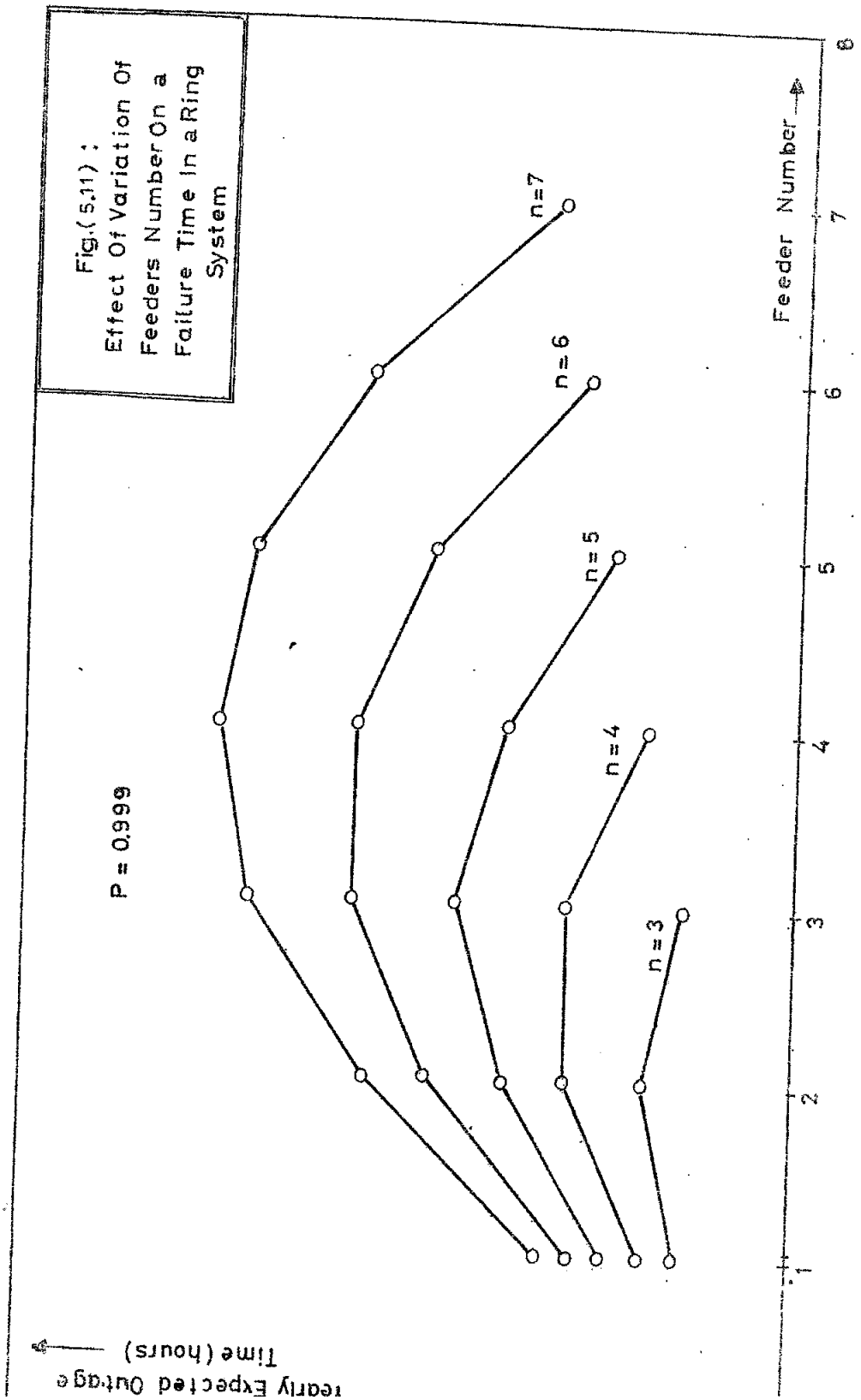


Fig.(5.11) :
Effect Of Variation Of
Feeders Number On a
Failure Time In a Ring
System
P = 0.999
n=7
n=6
n=5
n=4
n=3
Feeder Number
1
2
3
4
5
6
7
8
Yearly Expected Outage
Time (hours)

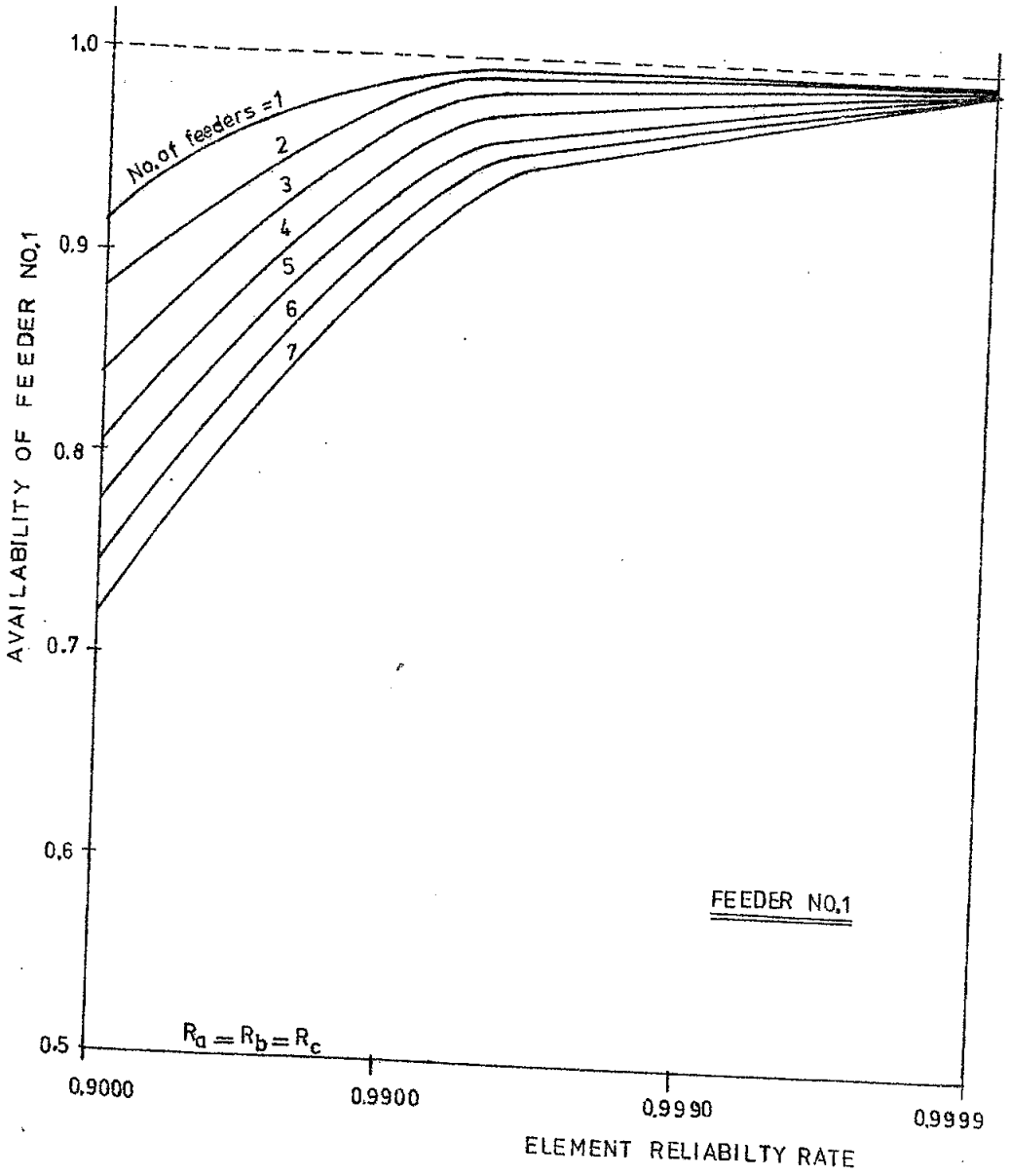


FIG.(5.12): AVAILABILITY VARIATION OF THE INDIVIDUAL RING SYSTEM FEEDERS WITH ELEMENTS RELIABILITY

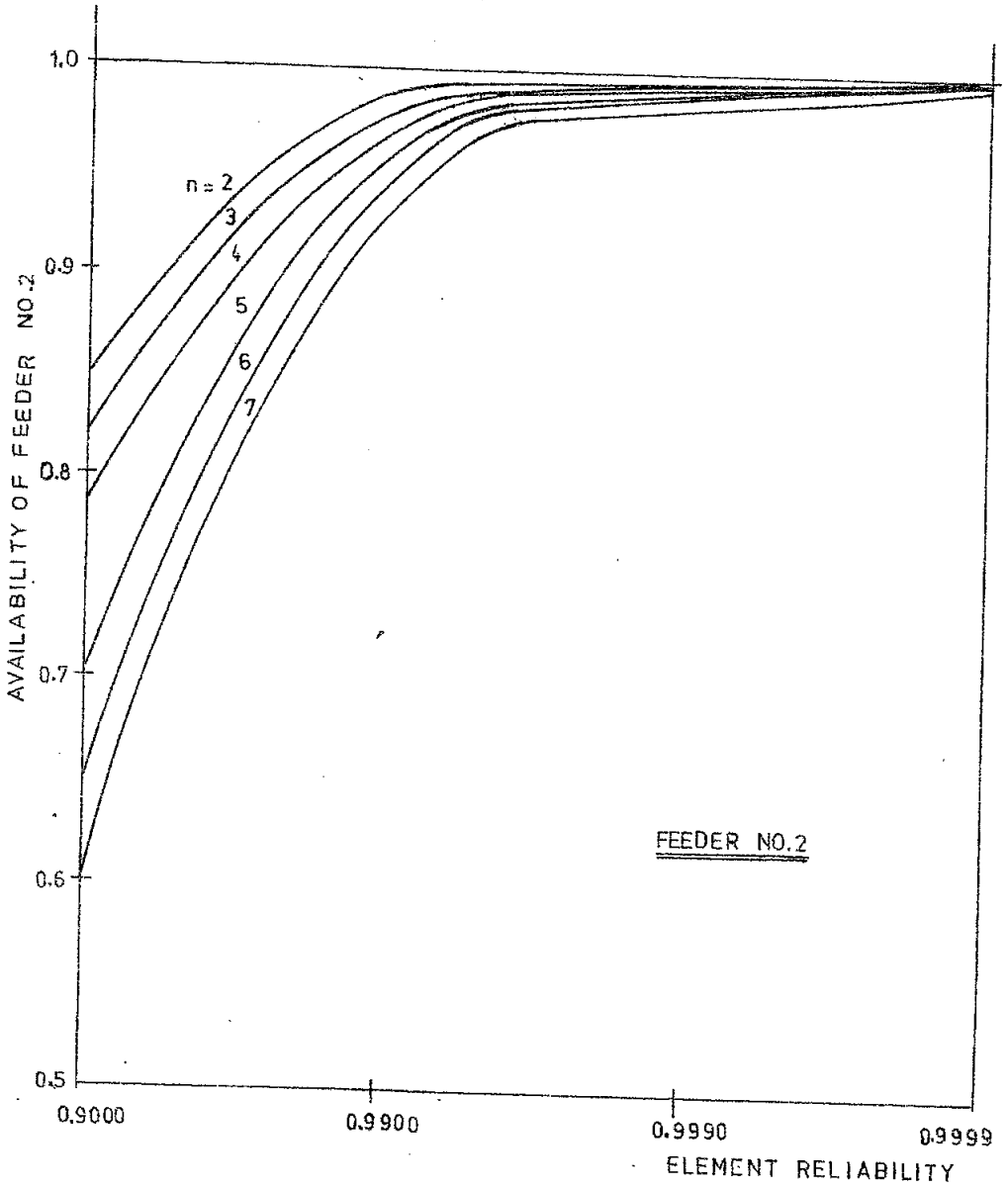


FIG.(5.13):AVAILABILITY VARIATION OF THE INDIVIDUAL FEEDERS OF THE RING SYSTEM WITH THE ELEMENT RELIABILITY

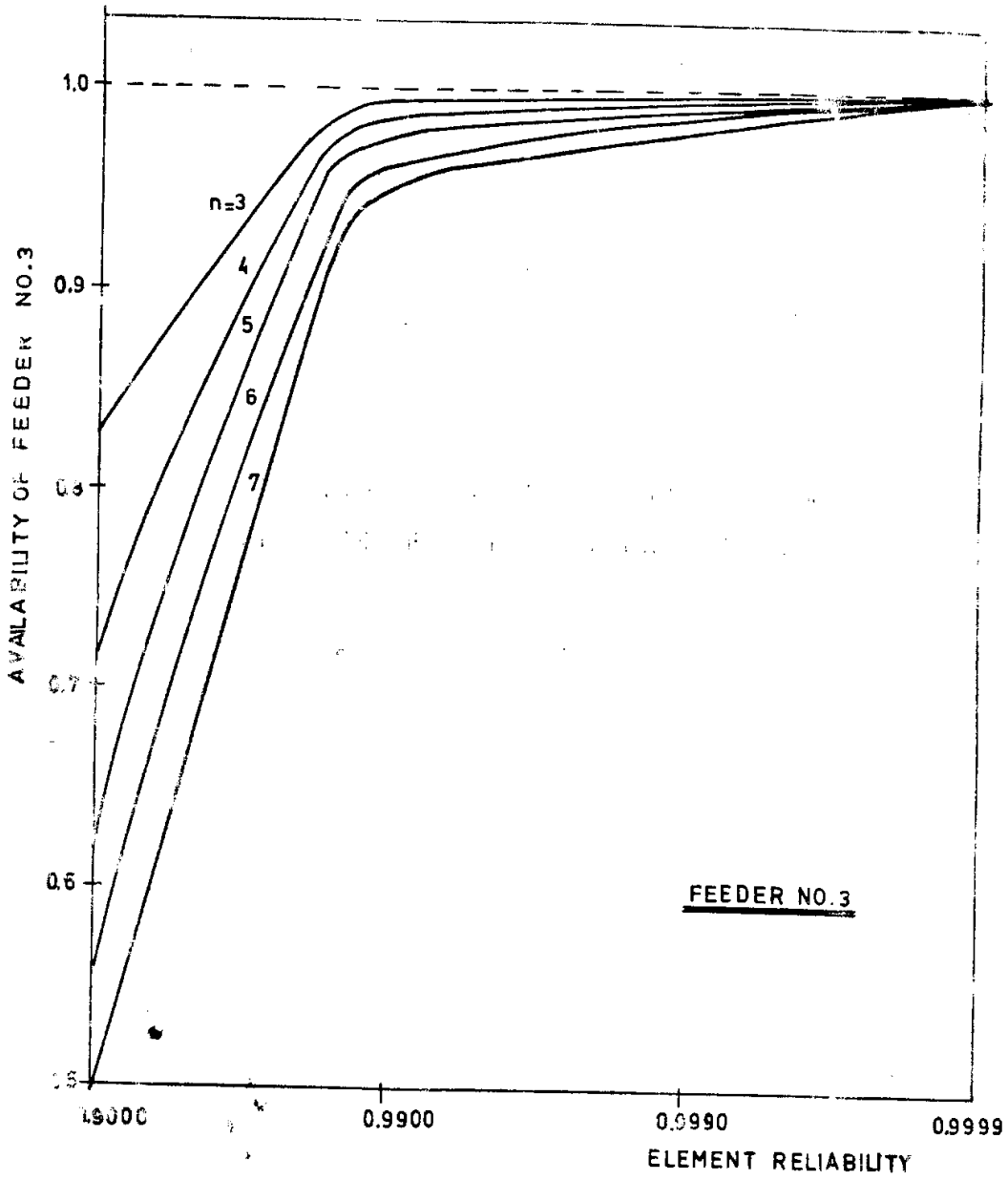


FIG.(5.14): AVAILABILITY VARIATION OF THE INDIVIDUAL RING SYSTEM FEEDERS WITH ELEMENT RELIABILITY

therefore

$$P = P_I^i + P_I^{n+1-i} - P_I^{n.1}$$

$$\therefore P_{II} = P_I + P_I^{2-1} - P_I^2$$

$$= P_I + P_I - P_I^2$$

$$= 2P_I - P_I^2$$

$$= P_I(2 - P_I) \qquad \ldots\ldots(5.45)$$

It is seen that this result is the same as that obtained in the previous analysis.

The unavailability of the system is then

$$Q_{II} = 1 + P_I - 2P_I = (1 + P_I)^2 \qquad \ldots\ldots(5.46)$$

and the yearly expected outage time in hours:

$$T_{fII} = 8760(1 + P_I^2 - 2P_I) \qquad \ldots\ldots(5.47)$$

$$= 8760(1 - P_I)^2$$

b. Breaker and a half scheme

This system is discussed previously in subsection(5.4.3) and given in fig.(5.9). The number of outgoing feeders in this system are two, i.e $n = 2$.

Thus the availabilites of feeder 1 and 2 are : -

$$P_1 = P_2 = P_I + (P_I)^{2+1-1} - (P_I)^{2+1}$$

$$= P_I + P_I^2 - P_I^3 \quad . \quad = P_{III} \qquad \ldots\ldots(5.48)$$

and this is the same formula as that given in equation (5.26).

The unavailability of this system is

$$Q_1 = Q_2 = 1-P_{III} = 1 + P_I^3 + P_I^2 - P_I \quad \ldots(5.49)$$

$$= (1 - P_I)\ (\ 1 - P_I^2\ )$$

and the yearly failure time in hours

$$T_{f1} = T_{f2} = 8760\ (1 - P_{III})$$

$$= 8760\ (1 + P_I^3 + P_I^2 - P_I) \qquad \text{Hours}$$

$$= 8760\ (1 - P_I)\ (\ 1 + P_I^2)\ \ldots.(5.50)$$

PART_ IV

GENERAL CONCLUSIONS, REFERANCES & APPENDICIES

CHAPTER -6

GENERAL CONCLUSIONS

6.1 Introduction

The work described throughout this thesis, is presented in three main parts. Part I deals with generating system reliability evaluation, part II deals with the transmission system reliability evaluation and part III deals with distribution system reliability considerations. Each part, excluding part III, consist of two chapters, one deals with the historical review of the methods and techniques and the other present the actual work which is done in this thesis with the discussion of its own results and conclusions.

Several tables are introduced and general expressions are developed for the generation, transmission and distribution system reliability evaluations. However, from the work as a hole some general conclusions and recomendations are drawn in this chapter.

6.2 Conclusions of Generating System Reliability Studies

Some general conclusions for generating system reliability evaluation may be classified as follows : -

c. For practical caculations, it was found convenient and sufficiently accurate to assume that the system consist of groups of units which is considered reasonably uniform. The size of the units should be selected that the deviations of individual sizes from the average within the group will give results within the desired accuracy.

d. As a result of the work, the N.E.A data for the period Jan.1972-Jan.1973 indicates that the durations of peak loads may not be exponentially distributed. This cannot, however, be regarded as a definite conclusion as the length of the study period is relatively short. This does not introduce any difficulty in regard to a long term static capacity study.

e. It can be clearly seen in this thesis that the computational effort required to determine the loss of load probability indices for any given system is considerably less than that required in the frequency and durtation approach. The level of application of probability mathematics is also much simpler. In terms of capacity planning and unit commitment it is doubtful if one methoed can be stated to be superior under all conditions.

6.3 Conclusion of Transmission system reliability considerations

Some general conclusions for transmission system reliability evaluation may be summerized as follows.

a. The major causes of troubles and failures that occur on Iraqi 132 K.V. transmission systems are due to insulator pollusion and meteorological phenomenas. The fluctuating environment in Iraq is found to have agreat effect on the temporary and permanent forced outages of lines and equipments in the three regions of Iraq. The distribution of the weather and failure durations are found to be exponential.

b. It is also found that there are good correlations between the meteorological phenomenas and the temporary outages that occur frequently on the transmission lines in this country. The thunderstorms has a great effect on line failures in both northern and southern regions. The humidity variations causes many troubles in the southern region. The dust storms has a great effect on lines especially in the central regions.

The ice storms and snow fall are found to have a considerable effect on line and equipment failures in the northern region.

probabilistic approach of forced outages is generally unrealistic and lead to unreasonably low estimates of the rate of occurrence of outage combination and gives poor information about quantitative system reliability to the system planners.

Our mathematical models use

6.4 Conclusions of distribution system reliability studies

The following points are concluded from the reliability studies of distribution system :-

a. The probabilistic approach is a powerfull technique which can be used accurately for reliability evaluations of a distributional networks. A general solution for estimation of reliability rate of simple configuration from more complicated systems is obtained using this technique(as shown in chapter 5) where the series, parallel, series parallel and other configurations are obtained from the bridge circuit using the 0 and 1 notation.

b. A general formula for reliability evaluation of the individual feeders of a ring system is obtained using the probabilistic approach and this formula can be modified to study more complicated networks such as H-type system and other T and networks and to investigate their performance characteristic when used in a practical schemes.

c. It was realized, that when the element reliability indices are low , the system reliability can be increased only by using equipment redundency. Of course this will lead to higher cost which may be totally or partiaby compensated for by the required good, reliable distrubution system, especially for heavy industrial loads.

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APPENDICIES

```
// JOB

LOG DRIVE   CART SPEC   CART AVAIL  PHY DRIVE
  0000        0001        0001        0000
                          002         0001

V2 M11   ACTUAL 16K  CONFIG 16K

// *              A P P E N D I X  ( A 1 )

// FOR
*ONE WORD INTEGERS

FEATURES SUPPORTED
 ONE WORD INTEGERS

CORE REQUIREMENTS FOR RRAT
 COMMON      0  VARIABLES      4  PROGRAM      36

RELATIVE ENTRY POINT ADDRESS IS 0007 (HEX)

END OF COMPILATION

// DUP

*DELETE              RRAT
CART ID 0001   DB ADDR  285D   DB CNT   0004

*STORE      WS  UA  RRAT
CART ID 0001   DB ADDR  3290   DB CNT   0034

// FOR
*ONE WORD INTEGERS
*LIST SOURCE PROGRAM
C              A P P E N D I X  ( A 1 )
C     SUBROUTINE CONSTRUCTING AND STORING THE OUTAG CAPACITY PROBABILITY
C     TABLE USING THE BINOMIAL EXPANSION
C     N = NUMBER OF GENERATING UNIT IN THE SYSTEM
C     C(I)= CAPACITY OF EACH UNIT (MW)
C     A(I) = CAPACITY OUTAGE LEVEL
C     P(I)=INDIVIDUAL(EXACT) OUTAGE PROBABILITY
C     PE(I)= CUMULATIVE OUTAGE PROBABILITY
      SUBROUTINE RRAT(N,C,A,PE,MJ,P)
      DIMENSION A(100),P(100),PE(100),C(100)
      M=N+1
      MJ=N-2
      PP=0.98
      Q=0.02
      A(1)=0.
      DO 100 I=1,N
       J=I+1
      A(J)=A(I)+C(I)
  100 CONTINUE
      FAN=RRAT(N)
       DO 101 KK=1,M
      K=KK-1
      X=FAN/(RRAT(N-K)*RRAT(K))
      D=FLOAT(K)
      DD=FLOAT(N-K)
```

```
      Y=PP**DD
      Z=Q**D
      PE(KK)=X*Y*Z
10    CONTINUE
      P(M)=PE(M,
       DO 102 I=1,N
      K=N-I+1
      KK=K+1
      P(K)=P(KK)+PE(K)
102   CONTINUE
      A(MJ)=0.
      P(MJ)=0.
      PE(MJ)=0.
      RETURN
      END

FEATURES SUPPORTED
 ONE WORD INTEGERS

CORE REQUIREMENTS FOR OCPT
 COMMON       0  VARIABLES     28  PROGRAM     268

RELATIVE ENTRY POINT ADDRESS IS 0024 (HEX)

END OF COMPILATION

// DUP

*DELETE              OCPT
CART ID 0001   DB ADDR  285D   DB CNT   0013

*STORE      WS  UA  OCPT
CART ID 0001   DB ADDR  3284   DB CNT   0013

// *          A P P E N D I X  ( A 2 )

// FOR
*ONE WORD INTEGERS
*LIST SOURCE PROGRAM
C          A P P E N D I X  ( A 2 )
C  DETERMINATION OF CUMULATIVE CAPACITY OUTAGE TABLE DUE TO ADDITION
C    OF ANEW UNIT
C    N= NUMBER OF GENERATING UNIT IN THE SYSTEM
C    A(I) = CAPACITY OUTAGE LEVEL
C    C(I)= CAPACITY OF EACH UNIT (MW)
C    P(I)=INDIVIDUAL(EXACT) OUTAGE PROBABILITY
C    PE(I)= CUMULATIVE OUTAGE PROBABILITY
        SUBROUTINE ROLSE(A,P,P1,P0,B1,B0,JJ)
       DIMENSION A(100),P(100),CO(1000),CP(1000)
        MM=0
       I=1
       J=1
3      X=(A(I)+B0)-(A(J)+B1)
       IF(X) 4,5,50
       MM=MM+1
       Y=P0*P(I)
       IF(Y) 1,1,2
```

```
      I=I+1
      GO TO 3
1     YY=P1*P(J)
      IF(YY) 7,7,6
6     CO(MM)=A(J)+B1
      CP(MM)=P1*P(J)
      J=J+1
       MM=MM+1
      GO TO 1
5     MM=MM+1
      XY=P0*P(I)
      IF(XY) 1,1,8
8     CO(MM)=A(I)+B0
      CP(MM)=P0*P(I)+P1*P(J)
      I=I+1
      J=J+1
      GO TO 3
50    MM=MM+1
      YX=P0*P(I)
      IF(YX) 1,1,9
9     CO(MM)=A(J)+B1
      CP(MM)=P0*P(I)+P1*(J)
      J=J+1
      GO TO 3
7     WRITE (3,10)
10    FORMAT(10X,' CAP.OUT                    CUM.PROB. ')
      CO(MM)=0.
      CP(MM)=0.
      JJ=MM-1
      DO 1000 IQ=1,MM
      A(IQ)=CO(IQ)
      P(IQ)=CP(IQ)
1000   CONTINUE




      RETURN
      END
```

```
FEATURES SUPPORTED
 ONE WORD INTEGERS

CORE REQUIREMENTS FOR ROLSE
 COMMON       0  VARIABLES   4020  PROGRAM     446

RELATIVE ENTRY POINT ADDRESS IS 0FCD (HEX)

END OF COMPILATION

// DUP
```

```
CART ID 0001   DB ADDR  285D   DB CNT   0020

*STORE      WS  UA  ROLSE
CART ID 0001   DB ADDR  3277   DB CNT   0020

// *          A P P E N D I X  ( A 3 )

// FOR
*ONE WORD INTEGERS
*LIST SOURCE PROGRAM
C        A P P E N D I X  ( A 3 )
C   SUBROUTINE (OXAL1) CALCULATING THE LOSS OF LOAD PROBABILITY FOR
C   AN EXISTING SYSTEM(USING SUBROUTINE OCPT)
C    YP= PEAK LOAD OF THE SYSTEM
C    YB= BASE LOAD OF THE SYSTEM
C    XT= TOTAL TIME PERIOD OF STUDY (P,U)
C    PLOL(I)= PROBABILITY OF LOSS OF LOAD (DAYS/YEAR)
C    SRL= STANDERD RISK LEVEL IN DAYS / YEAR
        SUBROUTINE OXAL1(YP,YB,J,MJ,A,P,CA,PLOL)
      DIMENSION A(100),X(100),PL(100),P(100),PLOL(100)
      MMM=MJ-1
       CA=A(MMM)
      XT=100.
      S=(YP-YB)/XT
      K=1
      X(1)=0.
      I=1
3     Y=CA-A(I)
      IF(YP-Y) 1,1,2
1     PL(I)=0.
      X(I)=0.
      XK=0.
      I=I+1
      GO TO 3
2     L=K+1
      X(L)=(YP-Y)/S
      XK=X(L)-X(K)
      TK=XK
      PL(I)=TK*P(I)
      I=I+1
      K=K+1
      IF(I-MMM) 3,3,4
4      KK=I-1
      PLS=0.
      DO 105 I=1,KK
      PLS=PLS+PL(I)
105   CONTINUE
      R=PLS*3.65
      PLOL(J)=R
      RETURN
      END

FEATURES SUPPORTED
 ONE WORD INTEGERS

CORE REQUIREMENTS FOR OXAL1
 COMMON       0  VARIABLES     432  PROGRAM      334
```

```
C       A P P E N D I X   A4
        SUBROUTINE OXAL3(YP,YB,J,JJ,A,P,CA,PLOL)
      DIMENSION A(100),X(100),PL(100),P(100),PLOL(10
      CA=A(JJ)
      MQ=JJ
      XT=100.
      K=1
      X(1)=0.
      S=(YP-YB)/XT
      I=1
3     Y=CA-A(I)
      IF(YP-Y) 1,1,2
1     PL(I)=0.
      X(I)=0.
      XK=0.
      I=I+1
      GO TO 3
2     L=K+1
      X(L)=(YP-Y)/S
      XK=X(L)-X(K)
      TK=XK
      PL(I)=TK*P(I)
      I=I+1
      K=K+1
      IF(I-MQ) 3,3,4
```

PAGE 6

```
4      KK=I-1
      PLS=0.
      DO 105 I=1,KK
      PLS=PLS+PL(I)
105   CONTINUE
      R=PLS*3.65
      PLOL(J)=R
      RETURN
      END
```

```
FEATURES SUPPORTED
 ONE WORD INTEGERS

CORE REQUIREMENTS FOR OXAL3
 COMMON       0  VARIABLES    422  PROGRAM    234

RELATIVE ENTRY POINT ADDRESS IS 01AD (HEX)

END OF COMPILATION

// DUP

*DELETE              OXAL3
CART ID 0001   DB ADDR  285D   DB CNT   0011

*STORE      WS  UA  OXAL3
CART ID 0001   DB ADDR  3289   DB CNT   0011
```

```
PAGE   -                    EE  MSC.        M.T...A.L.C.H.T.P.                    V1
      DIMENSION A(500),P(500),PLOL(500),C(500),PE(500)
      MKL=6
      WRITE(3,1047)
1047  FORMAT(1H1)
1040   READ(2,1042) B1
1042   FORMAT(F5.1)
      WRITE(3,1045) B1
1045  FORMAT(35X,F5.1,' (MW)  UNIT ADDITION SCHEME' ,/)
      N=21
      DO 1090 I=1,N
      C(I)=30.
1090   CONTINUE
      SUM=0.
      DO 1020 I=1,N
1020    SUM=SUM+C(I)
      WRITE(3,1001)
1001   FORMAT(3X,' YEAR OF STUDY          PEAK LOAD(MW)          TOTAL
     1APACITY          RISK LEVEL          UNIT ADD REQ ')
       WRITE(3,1044)
1044   FORMAT(2X,' ----------
     1---------- ')
      CALL OCPT(N,C,A,PE,MJ,P)
      J=1
      SRL=363.5
      YP=525.
      YB=320.
      KKK=1972
1021   CALL OXAL1(YP,YB,J,MJ,A,P,CA,PLOL)
1023   RISK=365.-PLOL(J)
      IF(RISK-SRL)  1005,1004,1004
1004   WRITE(3,1006) KKK,YP,CA,PLOL(J)
1006   FORMAT(3X,I14,10X,F14.2,10X,F14.2,10X,E14.7,10X,' NO ')
      KKK=KKK+1
      YP=YP+0.1*YP
      YB=YB+0.1*YB
      J=J+1
      IF(CA-SUM) 1021,1021,1022
1022   CALL OXAL3(YP,YB,J,JJ,A,P,CA,PLOL)
      GO TO 1023
1005   WRITE(3,1007) KKK,YP,CA,PLOL(J)
1007   FORMAT(3X,I14,10X,F14.2,10X,F14.2,10X,E14.7,10X,' YES ')
       IF(CA-SUM) 1030,1030,1031
1030     MJ=MJ+1
       A(MJK)=0.
       P(MJK)=0.
1031     JJ=J+1
      B0=0.
      P1=0.02
      P0=0.98
       WRITE(3,1010) B1,P1,P0
1010  FORMAT(' CAPACITY OF UNITADDED=',F9.3,10X,' OUTAGE RATE=',F9.5,  A
     1VAILABILITY=',F9.5)
       CALL ROLSE(A,P,P1,P0,B1,B0,JJ)
       CALL OXAL3(YP,YB,J,JJ,A,P,CA,PLOL)
1032   IF(KKK-1980) 1023,1023,1026
1026    CALL EXIT
COMPILATION DISCONTINUED
```

App. B1

NORMAL NUMBER OF DAYS OF OCCURRANCE OF THUNDERSTORM

at Iraqi Meteorological Stations.

Period: 1941 - 1973

STATIONS	JAN.	FEB.	MAR.	APR.	MAY.	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
MOSUL	0.5	019	2.6	4.3	3.2	0.2	0.1	C.0	0.2	1.3	1.5	0.3	15.1
KIRKUK	1.6	1.3	3.0	4.0	3.0	0.4	0.C	C.C	0.2	0.7	2.0	0.6	14.2
KHANAQIN	1.0	0.7	1.6	1.8	1.1	0.1	0.0	C.C	0.0	0.6	0.6	0.6	8.3
RUTBAH	0.4	0.4	0.9	1.8	2.6	0.1	0.0	C.C	0.1	1.3	1.1	0.5	0.2
HABBANIYA	1.0	0.3	2.5	3.1	1.7	0.0	0.0	C.C	0.1	0.6	1.6	1.2	12.6
BAGHDAD	0.8	0.3	1.9	2.5	1.6	0.0	0.0	C.C	0.2	0.8	1.2	0.8	10.6
HAI	0.8	0.6	2.4	2.9	1.8	0.1	0.0	C.C	0.1	0.8	1.6	0.8	11.9
DIWANIYA	0.9	0.7	1.5	2.0	1.9	0.0	0.0	C.C	0.0	0.7	1.2	0.7	9.9
NASIRIYA	1.0	0.7	2.0	2.7	1.8	0.0	0.0	C.0	0.0	0.7	1.6	0.9	11.4
BASRAH	1.3	1.1	2.7	3.4	2.1	0.0	0.0	0.0	0.0	0.7	1.6	1.4	14.3

App. B2

NORMAL NUMBER OF DAYS OF OCCURRENCES OF HAIL AT IRAN METEOROLOGICAL STATIONS.

PERIOD : 1941 - 1973

STATIONS	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
MOSUL	0.1	0.4	0.6	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7
KIRKUK	0.4	0.2	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4
KHANAQIN	0.1	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.7
RUTBAH	0.0	0.3	0.2	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.1	1.3
HABBANIYA	0.1	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
BAGHDAD	0.0	0.1	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
HAI	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
DIWANIYA	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
NASIRIYA	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
BASRAH	0.1	0.1	0.1	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.9

App. B3

NORMAL NUMBER OF DAYS OF OCCURRENCES OF DUSTSTORM

(VIS. 1000 METERS OR LOSS) AT IRAQI MET.STATIONS

PERIOD : 1941-1973

STATION	JAN	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
MOSUL	0.2	0.3	0.4	0.2	0.7	0.4	0.3	0.3	0.2	0.5	0.1	0.0	3.6
KIRKUK	0.3	0.3	0.4	0.5	0.9	0.5	0.4	0.4	0.3	0.6	0.3	0.0	4.9
KHANAQIN	0.0	0.5	0.4	0.7	1.1	0.1	0.3	0.2	0.3	0.4	0.0	0.1	4.1
RUTBAH	0.9	0.4	0.7	0.8	1.1	0.5	0.1	0.1	0.4	0.7	0.3	0.2	6.2
HABBANIYA	1.3	2.2	2.2	2.6	2.9	1.3	1.8	0.4	0.4	0.7	0.7	0.6	17.1
BAGHDAD	1.1	2.0	2.5	2.5	2.5	2.3	2.9	1.7	0.8	1.2	0.9	0.7	21.1
HAI	0.2	0.3	0.4	0.6	1.5	0.7	0.5	0.3	0.2	0.2	0.1	0.1	5.1
DIWANIYA	0.7	1.5	2.3	2.3	2.1	1.1	0.8	0.3	0.1	0.6	0.5	0.3	12.6
NASIRIYA	0.9	1.3	1.9	2.2	2.9	4.6	5.9	2.7	2.0	1.0	0.6	0.3	26.3
BASRAH	0.5	0.6	1.3	1.5	1.8	2.4	3.0	1.8	1.2	0.9	0.3	0.2	15.5

$\overline{X}$

App. B4

NORMAL MONTHLY RELATIVE HUMIDITY FOR IRAQI MET. STATIONS

PERIOD : 1941 - 1973.

M O N T H S & Y E A R

STATIONS	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
MOSUL	82	76	70	62	44	30	26	29	34	49	67	83	54
KIRKUK	72	65	58	49	33	20	18	18	21	30	50	69	42
KHANAQIN	68	60	56	45	30	19	17	18	20	28	49	68	40
RUTBAH	68	57	48	40	33	25	24	23	27	34	53	67	42
HABBANIYA	73	62	55	47	35	26	25	27	30	39	61	73	46
BAGHDAD	71	62	52	44	31	22	23	24	27	36	56	71	43
HAI	72	62	56	49	38	27	26	26	28	37	57	72	46
DIWANIYA	70	55	51	44	33	29	28	29	32	39	56	70	45
NASIRIYA	66	58	51	44	36	33	30	28	27	35	53	66	44
BASRAH	78	70	65	58	53	49	49	48	50	56	69	78	60

App. B5

NORMAL NUMBER OF DAYS OF OCCURRENCES OF SNOW

AT IRAQI METEOROLOGICAL STATIONS

PERIOD : 1941 - 1971

STATIONS	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR
MOSUL	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.7
KIRKUK	0.2	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8
KHANAGIN	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
RUTBAH	0.2	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6
HABBANIYA	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
BAGHDAD	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
HAI	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
DIWANIYA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NASIRIYA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASRAH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

App. B6

NORMAL NUMBER OF DAYS OF OCCURRENCES OF FOG AT IRAQI METEOROLOGICAL STATIONS

PERIOD : 1941 - 1970

STATIONS	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
MOSUL	5.6	1.5	1.1	0.7	0.0	0.0	0.0	0.0	0.0	0.0	2.2	5.2	16.3
KIRKUK	1.1	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6	3.1
KHANAQIN	0.6	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	1.8
RUTBAH	1.2	0.4	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.6	1.9	4.4
HABBANIYA	3.4	0.7	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.9	3.1	8.3
BAGHDAD	5.0	1.6	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.1	2.1	5.7	15.0
HAI	1.0	0.4	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.3	1.4	3.5
DIWANIYA	1.5	0.8	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.6	4.6
NASIRIYA	1.2	0.5	0.1	0.1	0.00	0.0	0.0	0.0	0.0	0.0	0.6	1.8	4.3
BASRAH	3.8	1.4	0.4	0.2	0.1	0.0	0.0	0.0	0.4	0.9	1.6	4.0	12.8

App. B7

Max. Wind Speed inknots for Baghdad Region - period 14 years.

YEAR	JAN.	FAB.	MAI.	APR.	MAY.	JUN	NULY	AUG.	SEP.	OCT.	NOV.	DEC.	Anual gusty Wind Speed in Knots	Durasion
1960	45	46	44	38	50	32	30	33	40	32	30	32	50	2mn
1961	18	22	25	27	25	25	25	28	28	25	25	28		
1962	20	20	27	25	20	18	18	20	15	40	20	32		
1963	25	30	38	58	38	38	20	25	13	35	32	35	50	4 min
1964	35	62	50	65	35	38	30	22	24	20	30	39	62,50,63	48 min,1 min, 1 Hours.
1965	48	30	30	50	25	22	25	30	18	22	22	32	50	2 min
1966	28	35	40	29	28	26	34	30	22	55	18	30	50	1 min
1967	27	28	45	35	30	35	32	30	30	42	25	30		
1968	34	38	42	40	60	32	35	33	24	30	25	40	60	20 min
1969	50	38	35	32	26	26	36	28	18	30	35	30	50	1 min
1970	22	22	28	30	23	23	20	20	20	25	20	18		
1971	15	26	30	30	22	22	25	25	25	18	20	20		
1972	24	20	25	28	30	22	22	20	16	18	20	18		
1973	26	26	28	22	20	26	24	26	20	20	22	20		

XIII

XIV

```
// JOB

LOG DRIVE   CART SPEC   CART AVAIL  PHY DRIVE
  0000        0001        0001        0000
                          0021        0001

V2 M11   ACTUAL 16K  CONFIG 16K

// *          A P P E N D I X  ( B 8 )

// FOR
*LIST SOURCE PROGRAM
*ONE WORD INTEGERS
C          A P P E N D I X  ( B 8 )
C    CORRELATION COEFFICIENT CALCULATION SUBROUTINE
C    X(I),Y(I)= TWO VARIABLES UNDER CONSIDERATION
C    R= CORRELATION COEFFICIENT
       SUBROUTINE CORL (N,X,Y,R)
       DIMENSION X(100),Y(100),E(100),HX(100),HY(100)
       SUMX=0.
       SUMY=0.
       DO 33 I=1,N
       SUMX=SUMX+X(I)
       SUMY=SUMY+Y(I)
33     CONTINUE
       SUM=0.
       DO 44 I=1,N
       E(I)=X(I)*Y(I)
       SUM=SUM+E(I)
44     CONTINUE
       SUMHX=0.
       SUMHY=0.
       DO 55 I=1,N
       HX(I)=(X(I))**2.
       HY(I)=(Y(I))**2.
       SUMHX=SUMHX+HX(I)
       SUMHY=SUMHY+HY(I)
55     CONTINUE
       P=FLOAT(N)
       A=P*SUM
       B=SUMX*SUMY
       D1=P*SUMHX
       D2=P*SUMHY
       D3=(SUMX)**2.
       D4=(SUMY)**2.
       D5=SQRT(D1-D3)
       D6=SQRT(D2-D4)
       R=(A-B)/(D5*D6)
       RETURN
       END

FEATURES SUPPORTED
 ONE WORD INTEGERS

CORE REQUIREMENTS FOR CORL
 COMMON       0  VARIABLES    632  PROGRAM    238
```

```
C   DETERMINATION OF CORRELATION COEFFICIENT BETWEEN THE TEMPORARY
C   OUTAGES AND METEOROLOGICAL PHENOMINA FOR IRAQ
C   H(DATA,A,B,C,D,E,F,G,H,I,J,)= HUMIDITY DATA FOR TEN MAJOR STATIONS
C   T(DATA,A,B,C,D,E,F,G,H,I,J,)= THUNDERSTORM DATA FOR TEN MAJOR STATIONS
C   D(DATA,A,B,C,D,E,F,G,H,I,J,)=    DUSTSTORM DATA FOR TEN MAJOR STATIONS
C    F(DATA,N,C,S)= TEMPORARY FAILURES DATA FOR THE THREE MAIN IRAQI REGIONS
      DIMENSION HA(20),HB(20),HC(20),HD(20),HE(20),HF(20),HG(20),HH(20)
      DIMENSION HI(20),HJ(20),FN(20),FC(20),FS(20)
      DIMENSION TA(20),TB(20),TC(20),TD(20),TE(20),TF(20),TG(20),TH(20)
      DIMENSION TI(20),TJ(20),DA(20),DB(20),DC(20),DD(20),DE(20),DF(20)
      DIMENSION DG(20),DI(20),DJ(20)  ,DH(20),HN(20),TN(20),HS(20)
      DIMENSION SA(20),SB(20),SF(20)
      DIMENSION X(100),Y(100)
      N=12
      READ(2,1)(HA(I),I=1,N)
1     FORMAT(12F4.1)
      READ(2,1)(HB(I),I=1,N)
      READ(2,1)(HC(I),I=1,N)
      READ(2,1)(HD(I),I=1,N)
      READ(2,1)(HE(I),I=1,N)
      READ(2,1)(HF(I),I=1,N)
      READ(2,1)(HG(I),I=1,N)
      READ(2,1)(HH(I),I=1,N)
      READ(2,1)(HI(I),I=1,N)
      READ(2,1)(HJ(I),I=1,N)
      READ(2,1)(TA(I),I=1,N)
      READ(2,1)(TB(I),I=1,N)
      READ(2,1)(TC(I),I=1,N)
      READ(2,1)(TD(I),I=1,N)
      READ(2,1)(TE(I),I=1,N)
      READ(2,1)(TF(I),I=1,N)
      READ(2,1)(TG(I),I=1,N)
      READ(2,1)(TH(I),I=1,N)
      READ(2,1)(TI(I),I=1,N)
      READ(2,1)(TJ(I),I=1,N)
      READ(2,1)(DA(I),I=1,N)
      READ(2,1)(DB(I),I=1,N)
      READ(2,1)(DC(I),I=1,N)
      READ(2,1)(DD(I),I=1,N)
      READ(2,1)(DE(I),I=1,N)
      READ(2,1)(DF(I),I=1,N)
      READ(2,1)(DG(I),I=1,N)
      READ(2,1)(DH(I),I=1,N)
      READ(2,1)(DI(I),I=1,N)
      READ(2,1)(DJ(I),I=1,N)
      READ(2,1)(SA(I),I=1,N)
      READ(2,1)(SB(I),I=1,N)
      READ(2,1)(SF(I),I=1,N)
5     FORMAT(12F4.2)
```

```
      READ(2,5)(FN(I),I=1,N)
      READ(2,5)(FC(I),I=1,N)
      READ(2,5)(FS(I),I=1,N)
      WRITE(3,30)
30    FORMAT(25X,' A V E R A G E  H U M I D I T Y ' )
      WRITE(3,33)
33    FORMAT(25X,' ---------------------------- ')
      DO 8  I=1,N
      HN(I)=(HA(I)+HB(I))/2.
      X(I)=HN(I)
      Y(I)=FN(I)
8     CONTINUE
      WRITE(3,88) (X(I),I=1,N)
88    FORMAT(' X(I)= ',12(F5.2,3X))
      WRITE(3,99) (Y(I),I=1,N)
99    FORMAT(' Y(I)= ',12(F5.2,3X))
      WRITE(3,10) R
10    FORMAT( ' CORRELATION FACTOR BETWEEN TEMPORARY FAILURE AND RELATIV
     1E HUMIDITY IN NORTH REGION OF IRAQ ' ,F10.5 )
      WRITE(3,1000)
1000  FORMAT(' ------------------------------------------------------------
     1----------------------------------------------',/)
      DO 11 I=1,N
      TN(I)=(TA(I)+TB(I))/2.
      X(I)=TN(I)
11    CONTINUE
      WRITE(3,88) (X(I),I=1,N)
      WRITE(3,99) (Y(I),I=1,N)
      CALL CORL (N,X,Y,R)
      WRITE(3,12) R
12    FORMAT( ' CORRELATION FACTOR BETWEEN TEMPORARY FAILURE AND THUNDER
     1STORMS IN NORTH REGION OF IRAQ = ',F10.5 )
      WRITE(3,1000)
      DO 20 I=1,N
      X(I)=(SA(I)+SB(I))/2.
20    CONTINUE
      WRITE(3,88) (X(I),I=1,N)
      WRITE(3,99) (Y(I),I=1,N)
      CALL CORL (N,X,Y,R)
      WRITE(3,211) R
211   FORMAT (' CORRELATION FACTOR BET.TEMP) FAILURE AND SNOW AT NORTHEN
     1 REGION = ',F10.5)
      WRITE(3,1000)
      DO 1001 I=1,N
      X(I)=(DA(I)+DB(I))/2.
1001  CONTINUE
      WRITE(3,88) (X(I),I=1,N)
      WRITE(3,99) (Y(I),I=1,N)
      CALL CORL (N,X,Y,R)
      WRITE(3,1002) R
1002  FORMAT(' CORRELATION FACT.BET.T.O.+DUSTST.IN NORTH=',F10.5)
```

```
      WRITE(3,1000)
      DO 15 I=1,N
      X(I)=TF(I)
      Y(I)=FC(I)
15    CONTINUE
      WRITE(3,88) (X(I),I=1,N)
      WRITE(3,99) (Y(I),I=1,N)
      CALL CORL (N,X,Y,R)
      WRITE(3,16) R
16    FORMAT( ' CORRELATION FACTOR BETWEEN TEMPORARY FAILURE AND THUNDER
     1STORMS IN CENTRAL REGION OF IRAQ = ',F10.5 )
      WRITE(3,1000)
      DO 17 I=1,N
      X(I)=DF(I)
      Y(I)=FC(I)
17    CONTINUE
      WRITE(3,88) (X(I),I=1,N)
      WRITE(3,99) (Y(I),I=1,N)
      CALL CORL (N,X,Y,R)
      WRITE(3,18) R
18    FORMAT( ' CORRELATION FACTOR BETWEEN TEMPORARY FAILURE AND DUSTST
     1RM WITH OUT TIME DELAY FOR CENTRAL REGION= ' ,F10.5 )
      WRITE(3,1000)
      K=2
      DO 111 J=2,11
      K=J+1
      I=J-1
      X(I)=DF(K)
111     CONTINUE
      X(11)=DF(1)
      X(12)=DF(2)
      WRITE(3,88) (X(I),I=1,N)
      WRITE(3,99) (Y(I),I=1,N)
      CALL CORL (N,X,Y,R)
      WRITE(3,188) R
188   FORMAT(' CORRELATION FACTOR BET.TEMP. FAILURE AND DUSTSTORM WITH
     1TIME DELAY(2M)FOR CENT.REG=',F10.5)
      WRITE(3,1000)
      K=2
      DO 112 J=3,11
      K=J+1
      I=J-2
      X(I)=DF(K)
112   CONTINUE
      X(10)=DF(1)
      X(11)=DF(2)
      X(12)=DF(3)
      WRITE(3,88) (X(I),I=1,N)
      WRITE(3,99) (Y(I),I=1,N)
      CALL CORL (N,X,Y,R)
```

```
 1.9   FORMAT(' CORRELATION FACTOR BET. TEMP.FAIL.AND DUST.(3M) DELAY= '
      1F10.5)
       WRITE(3,1000)
       DO 1003 I=1,N
       X(I)=HF(I)
1003    CONTINUE
       WRITE(3,88) (X(I),I=1,N)
       WRITE(3,99) (Y(I),I=1,N)
       CALL CORL (N,X,Y,R)
       WRITE(3,1004) R
1004   FORMAT(' CORREL.FACT.BET.T.O+HUMID.IN CENT.IRAQ=',F10.5)
       WRITE(3,1000)
       DO 13 I=1,N
       HS(I)=(HI(I)+HJ(I))/2.
       X(I)=HS(I)
       Y(I)=FS(I)
13     CONTINUE
       WRITE(3,88) (X(I),I=1,N)
       WRITE(3,99) (Y(I),I=1,N)
       CALL CORL (N,X,Y,R)
       WRITE(3,14) R
14     FORMAT(' CORRELATION FACTOR BETWEEN TEMPORARY FAILURE AND RELATIV
      1E HUMIDITY IN SOUTH REGION OF IRAQ ',F10.5 )
       WRITE(3,1000)
       DO 19 I=1,N
       X(I)=(HI(I)+HH(I)+HJ(I))/3.
       Y(I)=FS(I)
19     CONTINUE
       WRITE(3,88) (X(I),I=1,N)
       WRITE(3,99) (Y(I),I=1,N)
       WRITE(3,14) R
       WRITE(3,1000)
       DO 21 I=1,N
       X(I)=(TH(I)+TI(I)+TJ(I))/3.
       Y(I)=FS(I)
21     CONTINUE
       WRITE(3,88) (X(I),I=1,N)
       WRITE(3,99) (Y(I),I=1,N)
       CALL CORL (N,X,Y,R)
       WRITE(3,22) R
22     FORMAT(' CORRELATION FACTOR BETWEEN TEMPORARY FAILURE AND THUNDER
      1STORMS IN SOUTH REGION OF IRAQ = ',F10.5 )
       WRITE(3,1000)
       DO 23 I=1,N
       X(I)=(DH(I)+DI(I)+DJ(I))/3.
       Y(I)=FS(I)
23     CONTINUE
       WRITE(3,88) (X(I),I=1,N)
       WRITE(3,99) (Y(I),I=1,N)
```

```
      CALL CORL (N,X,Y,R)
      WRITE(3,24) R
24    FORMAT( ' CORRELATION FACTOR BETWEEN TEMPORARY FAILURE AND DUSTSTO
     1RM WITH OUT TIME DELAY FOR SOUTH REGION= ' ,F10.5 )
      WRITE(3,1000)
      K=2
      DO 1005 J=2,11
      K=J+1
      I=J-1
      X(I)=(DI(K)+DJ(K))/2.
1005   CONTINUE
      X(11)=(DI(1)+DJ(1))/2.
      X(12)=(DI(2)+DJ(2))/2.
      WRITE(3,88) (X(I),I=1,N)
      WRITE(3,99) (Y(I),I=1,N)
      CALL CORL (N,X,Y,R)
      WRITE(3,1006) R
1006  FORMAT(' CORRELATION FACT.BET.T.O.+DUSTST.IN SOUTH(2M)D=',F10.5)
      WRITE(3,1000)
      K=2
      DO 1007 I=3,11
      K=J+1
      I=J-2
      X(I)=(DI(K)+DJ(K))/2.
1007   CONTINUE
      X(10)=(DI(1)+DJ(1))/2.
      X(11)=(DI(2)+DJ(2))/2.
      X(12)=(DI(3)+DJ(3))/2.
      WRITE(3,88) (X(I),I=1,N)
      WRITE(3,99) (Y(I),I=1,N)
      CALL CORL (N,X,Y,R)
      WRITE(3,1008) R
1008  FORMAT(' CORRELATION FACT.BET.T.O.+DUSTST.IN SOUTH(3M)D=',F10.5)
      WRITE(3,1000)
      CALL EXIT
COMPILATION DISCONTINUED

M 14 SYSTEM PROGRAM DETECTED MONITOR CONTROL RECORD
```

```
C
C
C*** SLN= SOUTH TRANSMISSION LINE NUMBER
C*** AIL= TRANSMISSION LINE LENGTH
C*** ASLL= AVERAGE SOUTH LINE LENGTH
C*** ACTLL= AVERAGE CENTRAL TRANSMISSION LINE LENGTH
C*** ANTLL= AVERAGE NORTH TRANSMISSION LINE LENGTH
C*** ACLLL= AVERAGE TIE LINE LENGTH
C*** AITLL=  AVERAGE IRAQ LINE LENGTH
C*** WNN= EXPECTED NORMAL WEATHER DURATION
C ** WNN= EXPECTED NORMAL WEATHER DURATION  (HOURS)
C*** SENDN= OUTAGE NUMBER  WETHER DURATION
C*** SENDN= OUTAGE NUMBERDURING NORMAL WEATHER AT SOUTH REGION
C     SENDS=OUTAGE NUMBER DURING STORMY WEATHER AT SOUTH REGION
C     DN= FAILURE RATE DURING NORMAL WEATHER
C     DP= FAILURE RATE DURING STORMY WEATHER
C     DAV= AVERAGE OUTAG RATAE
C     AV(I)= AVAILABILITY
C     UAV(I)= UNAVAILABILITY
C*** ET(I)= EXPECTED YEARLY OUTAG TIME
C*** CENDS=CENTRAL REGION PERMANENT OUTAGE DURING STORMY WEATHER
C*** CENDN=CENTRAL REGION PERMANENT OUTAGE DURING NORMAL WEATHER
C*** CELNS= TIE LINE OUTAGE NUMBER DURING STORMY WEATHER
      DIMENSION R(100),A(100),Y(100),X(100),AV(100),UAV(100),ET(100)
      READ(2,10)(A(I),I=1,52)
10    FORMAT(14F5.1/14F5.1/12F5.1/12F5.1)
      SUMS=0.
      DO 711 I=1,14
      SUMS=SUMS+A(I)
      SLN=14.
711   CONTINUE
      SUMCT=0.
      DO 2    I=15,28
      SUMCT=SUMCT+A(I)
2     CONTINUE
      SUMCL=0.
      DO 3    I=29,40
      SUMCL=SUMCL+A(I)
3     CONTINUE
      SUMN=0.
      DO 4    I=41,52
      SUMN=SUMN+A(I)
4     CONTINUE
      SUMI=SUMS+SUMCT+SUMN
      ASLL=SUMS/14.
      ACTLL=SUMCT/14.
      ANTLL=SUMN/12.
      ACLLL=SUMCL/12.
      AITLL=SUMI/40.
      WRITE(3,500)
500   FORMAT(1H1)
      WRITE(3,6)
6     FORMAT(28X,'IRAQ TRANSMISSION LINE LENGTH EVALUATION ')
      WRITE(3,55)
55    FORMAT(' ------------------------------------------------------------
     1---------- ')
      WRITE(3,5)
5     FORMAT( '  SOUTHERN REGION                CENTRAL REGION
```

```
      WRITE(3,7)
7     FORMAT(' TOTAL.KM  AVERAGE.          TOTAL.KM  AVERAGE.
     1     TOTAL.KM  AVERAGE.')
      WRITE(3,55)
      WRITE(3,8)SUMS,ASLL,SUMT,ACTLL,SUMN,AVTLL
8     FORMAT(  F8.2,6X,F6.2,10X,F8.2,6X,F6.2,10X,F8.2,6X,F6.2)
      WRITE(3,100)AITLL
100   FORMAT('AVERAGE LENGTH PER LINE IN KM. FOR IRAQ= ',F6.2)
      WRITE(3,9)SUMI
9     FORMAT(' TOTAL LENGTH OF IRAQ TRANSMISIION LINES.KM= ',F8.2)
      OP=5.
      S=1.5
      WNN=650.
      SFNDS=4.
      SFNDN=15.
      SK=S/(S+WNN)
      DN=SFNDN/(SLN*OP*ASLL*(1.-SK))
      DSS=SFNDS/(SLN*OP*SK*ASLL)
      DP=DSS
      DAV=(DN*WNN/(S+WNN))+(DP*S/(S+WNN))
      WRITE(3,99)
99    FORMAT(15X,' SOUTHERN REGION T.LINES RELIABILITY MEASURES CALCUL
     1ION ',//)
      WRITE(3,55)
      ADOFH=2.
      DO 101 I=1,14
      R(I)=DAV*A(I)
101   CONTINUE
      DO 106 I=1,14
      X(I)=DN*A(I)
106   CONTINUE
      DO 102 I=1,14
      Y(I)=DSS*A(I)
102   CONTINUE
      WRITE(3,11)
11    FORMAT(' REPAIR.TIME.          AVE.OUT.RAT          AVE.OUT.RATE
     1  EQU.OUT.RATE    ')
      WRITE(3,12)
12    FORMAT('    PER YEAR.HOURS     DURING.N.WEATH.      DURING.S.WEATH.
     1  CONSIDERING.TWO.STATE  ')
      WRITE(3,14)
14    FORMAT('                       /KM/YEAR             /KM/YEAR
     1  /KM/YEAR    ')
      WRITE(3,15)ADOFH,DN,DSS,DAV
15    FORMAT(2X,4(E14.6,5X))
      WRITE(3,500)
        WRITE(3,507)
507    FORMAT(////)
      WRITE (3,506)
506   FORMAT(35X,' TABLE(4.13  ) ')
      WRITE(3,99)
      WRITE(3,55)
1     ADOFY=8760./ADOFH
      WRITE(3,300) ADOFH
      DO 103 I=1,14
      AV(I)=ADOFY/(ADOFY+R(I))
103   CONTINUE
      DO 104 I=1,14
      UAV(I)=1.-AV(I)
```

```
104   CONTINUE
      DO 105 I=1,14
      ET(I)=AV(I)*8760.
105   CONTINUE
      WRITE(3,17)
17    FORMAT('   132.K.V. LINE      NORMAL.W      STORMY.W      EQUIVALE.
     1LINE AVA-       EXP.YEARLY  ')
      WRITE(3,171)
171   FORMAT( '                                OUT.R/Y       OUT.R/Y       OUT.R/Y
     1 ILABILITY      OUT.TIME/Y  ')
      WRITE(3,505)
505   FORMAT(' ------------------   ---------   ----------   ----------
     1  ----------     ---------- ')
      WRITE(3,18)X(1),Y(1),R(1),AV(1),ET(1)
      WRITE(3,19)X(2),Y(2),R(2),AV(2),ET(2)
      WRITE(3,20)X(3),Y(3),R(3),AV(3),ET(3)
      WRITE(3,21)X(4),Y(4),R(4),AV(4),ET(4)
      WRITE(3,22)X(5),Y(5),R(5),AV(5),ET(5)
      WRITE(3,23)X(6),Y(6),R(6),AV(6),ET(6)
      WRITE(3,24)X(7),Y(7),R(7),AV(7),ET(7)
      WRITE(3,25)X(8),Y(8),R(8),AV(8),ET(8)
      WRITE(3,26)X(9),Y(9),R(9),AV(9),ET(9)
      WRITE(3,27)X(10),Y(10),R(10),AV(10),ET(10)
      WRITE(3,28)X(11),Y(11),R(11),AV(11),ET(11)
      WRITE(3,29)X(12),Y(12),R(12),AV(12),ET(12)
      WRITE(3,30)X(13),Y(13),R(13),AV(13),ET(13)
      WRITE(3,31)X(14),Y(14),R(14),AV(14),ET(14)
18    FORMAT(' NAJIBIYA-HARTHA1    ',5(F9.6,4X))
19    FORMAT(' NAJIBIYA-HARTHA2    ',5(F9.6,4X))
20    FORMAT(' NAJIBIYA-SHUAIBA    ',5(F9.6,4X))
21    FORMAT(' NAJIBIYA-SHUAIBA2   ',5(F9.6,4X))
22    FORMAT(' SHUAIBA-ABUFLLUS1   ',5(F9.6,4X))
23    FORMAT(' SHUAIBA-ABUFLLUS2   ',5(F9.6,4X))
24    FORMAT(' SHUAIBA-UMQASSR 1   ',5(F9.6,4X))
25    FORMAT(' SHUAIBA-UMQASSR 2   ',5(F9.6,4X))
26    FORMAT(' AMMARA-HARTHA       ',5(F9.6,4X))
27    FORMAT(' NASSIRIYA-SHUAIBA1  ',5(F9.6,4X))
28    FORMAT(' NASSIRIYA-SHUAIBA2  ',5(F9.6,4X))
29    FORMAT(' NASSIRIYA-RIFAI     ',5(F9.6,4X))
30    FORMAT(' KUTT-AMMARA         ',5(F9.6,4X))
31    FORMAT(' NASSIRIYA-SAMAWA    ',5(F9.6,4X))
      ADOFH=ADOFH+4.
      IF(ADOFH-6.) 1,1,32
32    WRITE(3,55)
      WRITE(3,500)
      CTLN=14.
      CFNDS=4.
      CFNDN=26.
      DN=CFNDN/(CTLN*OP*ACTLL*(1.-SK))
      DP=CFNDS/(CTLN*OP*ACTLL*SK)
      DSS=DP
      DAV=(DN*WNN/(S+WNN))+(DP*S/(S+WNN))
      ADOFH=2.
      WRITE(3,11)
      WRITE(3,12)
      WRITE(3,14)
      WRITE(3,15)ADOFH,DN,DSS,DAV
      DO 107 I=15,28
```

```
104   CONTINUE
      DO 105 I=1,14
      ET(I)=LA(I)*BTEC.
105   CONTINUE
      WRITE(3,17)
17    FORMAT(' 132.K.W. LINE     NORMAL.W      STORMY.W      EQUIVALE
     1NCE AVA-      EXP.YEARLY  ')
      WRITE(3,171)
171   FORMAT( '                          OUT.R/Y       OUT.R/Y       OUT.R/Y
     1 ILABILITY     OUT.TIME/Y  ')
      WRITE(3,505)
505   FORMAT(' ----------------   ---------   ----------   ----------
     1  ----------    ---------  ')
      WRITE(3,18)X(1),Y(1),R(1),AV(1),ET(1)
      WRITE(3,19)X(2),Y(2),R(2),AV(2),ET(2)
      WRITE(3,20)X(3),Y(3),R(3),AV(3),ET(3)
      WRITE(3,21)X(4),Y(4),R(4),AV(4),ET(4)
      WRITE(3,22)X(5),Y(5),R(5),AV(5),ET(5)
      WRITE(3,23)X(6),Y(6),R(6),AV(6),ET(6)
      WRITE(3,24)X(7),Y(7),R(7),AV(7),ET(7)
      WRITE(3,25)X(8),Y(8),R(8),AV(8),ET(8)
      WRITE(3,26)X(9),Y(9),R(9),AV(9),ET(9)
      WRITE(3,27)X(10),Y(10),R(10),AV(10),ET(10)
      WRITE(3,28)X(11),Y(11),R(11),AV(11),ET(11)
      WRITE(3,29)X(12),Y(12),R(12),AV(12),ET(12)
      WRITE(3,30)X(13),Y(13),R(13),AV(13),ET(13)
      WRITE(3,31)X(14),Y(14),R(14),AV(14),ET(14)
18    FORMAT(' NAJIBIYA-HARTHA1    ',5(F9.6,4X))
19    FORMAT(' NAJIBIYA-HARTHA2    ',5(F9.6,4X))
20    FORMAT(' NAJIBIYA-SHUAIBA    ',5(F9.6,4X))
21    FORMAT(' NAJIBIYA-SHUAIBA2   ',5(F9.6,4X))
22    FORMAT(' SHUAIBA-ABUFLLUS1   ',5(F9.6,4X))
23    FORMAT(' SHUAIBA-ABUFLLUS2   ',5(F9.6,4X))
24    FORMAT(' SHUAIBA-UMQASSR 1   ',5(F9.6,4X))
25    FORMAT(' SHUAIBA-UMQASSR 2   ',5(F9.6,4X))
26    FORMAT(' AMMARA-HARTHA       ',5(F9.6,4X))
27    FORMAT(' NASSIRIYA-SHUAIBA1  ',5(F9.6,4X))
28    FORMAT(' NASSIRIYA-SHUAIBA2  ',5(F9.6,4X))
29    FORMAT(' NASSIRIYA-RIFAI     ',5(F9.6,4X))
30    FORMAT(' KUTT-AMMARA         ',5(F9.6,4X))
31    FORMAT(' NASSIRIYA-SAMAWA    ',5(F9.6,4X))
      ADOFH=ADOFH+4.
      IF(ADOFH-6.) 1,1,32
32    WRITE(3,55)
      WRITE(3,500)
      CTLN=14.
      CFNDS=4.
      CFNDN=26.
      DN=CFNDN/(CTLN*OP*ACTLL*(1.-SK))
      DP=CFNDS/(CTLN*OP*ACTLL*SK)
      DSS=DP
      DAV=(DN*WNN/(S+WNN))+(DP*S/(S+WNN))
      ADOFH=2.
      WRITE(3,11)
      WRITE(3,12)
      WRITE(3,14)
      WRITE(3,15)ADOFH,DN,DSS,DAV
      DO 107 I=15,28
      R(I)=DAV*A(I)
```

```
107   CONTINUE
      DO 113 I=15,28
      X(I)=DN*A(I)
113   CONTINUE
      DO 108 I=15,28
      Y(I)=DSS*A(I)
108   CONTINUE
      WRITE(3,500)
        WRITE(3,507)
       WRITE(3,5066)
5066  FORMAT(35X,' TABLE(4,14  ) ')
       WRITE(3,110)
110   FORMAT(15X,' CENTRAL IRAQ TRANSMISSION LINE RELIABILITY INDICIES
     1EVALUATION ',//)
74    ADOFY=8760./ADOFH
      DO 109 I=15,28
      AV(I)=ADOFY/(ADOFY+R(I))
109   CONTINUE
      DO 111 I=15,28
      UAV(I)=1.-AV(I)
111   CONTINUE
      DO 112 I=15,28
      ET(I)=UAV(I)*8760.
112   CONTINUE
        WRITE(3,55)
      WRITE(3,300) ADOFH
      WRITE(3,17)
      WRITE(3,171)
       WRITE(3,505)
      WRITE(3,60)X(15),Y(15),R(15),AV(15),ET(15)
      WRITE(3,61)X(16),Y(16),R(16),AV(16),ET(16)
      WRITE(3,62)X(17),Y(17),R(17),AV(17),ET(17)
      WRITE(3,63)X(18),Y(18),R(18),AV(18),ET(18)
      WRITE(3,64)X(19),Y(19),R(19),AV(19),ET(19)
      WRITE(3,65)X(20),Y(20),R(20),AV(20),ET(20)
      WRITE(3,66)X(21),Y(21),R(21),AV(21),ET(21)
      WRITE(3,67)X(22),Y(22),R(22),AV(22),ET(22)
      WRITE(3,68)X(23),Y(23),R(23),AV(23),ET(23)
      WRITE(3,69)X(24),Y(24),R(24),AV(24),ET(24)
      WRITE(3,70)X(25),Y(25),R(25),AV(25),ET(25)
      WRITE(3,71)X(26),Y(26),R(26),AV(26),ET(26)
      WRITE(3,72)X(27),Y(27),R(27),AV(27),ET(27)
      WRITE(3,73)X(28),Y(28),R(28),AV(28),ET(28)
60    FORMAT(' SAMAWA-SHAMIYA      ',5(F9.6,4X))
61    FORMAT(' SHAMIYA-HILLA       ',5(F9.6,4X))
62    FORMAT(' KUT-AZIZIYA 1       ',5(F9.6,4X))
63    FORMAT(' KUT-AZIZIYA 2       ',5(F9.6,4X))
64    FORMAT(' AZIZIYA-S.BAGHDAD1  ',5(F9.6,4X))
65    FORMAT(' AZIZIYA-S.BAGHDAD2  ',5(F9.6,4X))
66    FORMAT(' DURA-HILLA 1        ',5(F9.6,4X))
67    FORMAT(' DURA-HILLA2         ',5(F9.6,4X))
68    FORMAT(' TAJI-RAMADI 1       ',5(F9.6,4X))
69    FORMAT(' TAJI-RAMADI   2     ',5(F9.6,4X))
70    FORMAT(' TAJI-SAMERRA  1     ',5(F9.6,4X))
71    FORMAT(' TAJI-SAMERRA  2     ',5(F9.6,4X))
72    FORMAT(' N.BAGHDAD-BAQUBA 1  ',5(F9.6,4X))
73    FORMAT(' N.BAGHDAD-BAQUBA 2  ',5(F9.6,4X))
      ADOFH=ADOFH+4.
      IF(ADOFH-6. ) 74,74,75
```

```
75    WRITE(3,55)
      WRITE(3,500)
      WRITE(3,55)
      WNTLN=12.
      WNFDN=35.
      DN=WNFDN/(WNTLN*OP*ANTLL)
      DAV=DN
      WRITE(3,301) DN
301   FORMAT(' NORTHEN REGION FAILURE RATE/Y/KM/LINE= ',E14.6)
      WRITE(3,55)
      DSS=0.
      DP=DSS
      DO 114 I=1,52
      R(I)=DAV*A(I)
114   CONTINUE
      DO 115 I=1,52
      Y(I)=DSS*A(I)
115   CONTINUE
      DO 117 I=41,52
      X(I)=DN*A(I)
117   CONTINUE
      ADOFH=2.
       WRITE(3,500)
        WRITE(3,507)
       WRITE(3,5067)
5067  FORMAT(35X,' TABLE(4.15  ) ')
      WRITE(3,76)
76    FORMAT(15X,' NORTHEN REGION T.LINES RELIABILITY INDICIES CALCULAT
     1ON ')
       WRITE(3,55)
57    ADOFY=8760./ADOFH
      WRITE(3,300) ADOFH
300   FORMAT(' AVERAGE REPARING TIME IN HOURS= ',F5.1)
      DO 116 I=41,52
      AV(I)=ADOFY/(ADOFY+R(I))
116   CONTINUE
      DO 118 I=41,52
      UAV(I)=1.-AV(I)
118   CONTINUE
      DO 119 I=41,52
      ET(I)=UAV(I)*8760.
119   CONTINUE
      WRITE(3,17)
      WRITE(3,171)
       WRITE(3,505)
      WRITE(3,80)X(41),Y(41),R(41),AV(41),ET(41)
      WRITE(3,81)X(42),Y(42),R(42),AV(42),ET(42)
      WRITE(3,82)X(43),Y(43),R(43),AV(43),ET(43)
      WRITE(3,83)X(44),Y(44),R(44),AV(44),ET(44)
      WRITE(3,84)X(45),Y(45),R(45),AV(45),ET(45)
      WRITE(3,85)X(46),Y(46),R(46),AV(46),ET(46)
      WRITE(3,86)X(47),Y(47),R(47),AV(47),ET(47)
      WRITE(3,87)X(48),Y(48),R(48),AV(48),ET(48)
      WRITE(3,88)X(49),Y(49),R(49),AV(49),ET(49)
      WRITE(3,89)X(50),Y(50),R(50),AV(50),ET(50)
      WRITE(3,90)X(51),Y(51),R(51),AV(51),ET(51)
      WRITE(3,91)X(52),Y(52),R(52),AV(52),ET(52)
80    FORMAT(' SAMERRA-DIBIS 1      3(F9.6,4X))
81    FORMAT(' SAMERRA-DIBIS 2      5(F9.6,4X))
```

```
 82    FORMAT(' KIRKUK-SULAIMANIYA1',5(F9.6,4X))
 83    FORMAT(' KIRKUK-SULAIMANIYA2',5(F9.6,4X))
 84    FORMAT(' DIBIS-ERBIL   1     ',5(F9.6,4X))
 85    FORMAT(' DIBIS-ERBIL   2     ',5(F9.6,4X))
 86    FORMAT(' ERBIL-MOUSEL  1     ',5(F9.6,4X))
 87    FORMAT(' ERBIL-MOUSEL  2     ',5(F9.6,4X))
 88    FORMAT(' MOUSEL-HAMMAM 1     ',5(F9.6,4X))
 89    FORMAT(' MOUSEL-HAMMAM 2     ',5(F9.6,4X))
 90    FORMAT(' KIRKUK-DIBIS  1     ',5(F9.6,4X))
 91    FORMAT(' KIRKUK-DIBIS  2     ',5(F9.6,4X))
       ADOFH=ADOFH+4.
       IF(ADOFH-6. ) 57,57,58
 58    WRITE(3,55)
       WRITE(3,500)
       CTLTN=12.
       CTLLL=6.
       CFLNS=1.
       DN=CTLLN/(CTLTN*OP*ACLLL*(1.-SK))
       OP=CFLNS/(CTLTN*OP*ACLLL*SK)
       DSS=DP
       DAV=(DN*WNN/(S+WNN))+(DP*S/(S+WNN))
       ADOFH=2.
       WRITE(3,11)
       WRITE(3,12)
       WRITE(3,14)
       WRITE(3,15)ADOFH,DN,DSS,DAV
       WRITE(3,55)
       DO 120 I=29,40
       R(I)=DAV*A(I)
120    CONTINUE
       DO 121 I=29,40
       Y(I)=DSS*A(I)
121    CONTINUE
       DO 125 I=29,40
       X(I)=DN*A(I)
125    CONTINUE
       WRITE(3,500)
         WRITE(3,507)
        WRITE(3,5068)
5068   FORMAT(35X,' TABLE(4,16  ) ')
       WRITE(3,59)
59     FORMAT(35X,' CENTRAL IRAQ TIE LINES REL.ABILITY INDICIES CALCUL
      1TION ')
       WRITE(3,55)
200    ADOFY=8760./ADOFH
       WRITE(3,300) ADOFH
       DO 122 I=29,40
       AV(I)=ADOFY/(ADOFY+R(I))
122    CONTINUE
       DO 123 I=29,40
       UAV(I)=1.-AV(I)
123    CONTINUE
       DO 124 I=29,40
       ET(I)=UAV(I)*8760.
124    CONTINUE
       WRITE(3,17)
       WRITE(3,171)
        WRITE(3,505)
```

```
      WRITE(3,34)X(30),Y(30),R(30),AV(30),ET(30)
      WRITE(3,35)X(31),Y(31),R(31),AV(31),ET(31)
      WRITE(3,36)X(32),Y(32),R(32),AV(32),ET(32)
      WRITE(3,37)X(33),Y(33),R(33),AV(33),ET(33)
      WRITE(3,38)X(34),Y(34),R(34),AV(34),ET(34)
      WRITE(3,39)X(35),Y(35),R(35),AV(35),ET(35)
      WRITE(3,40)X(36),Y(36),R(36),AV(36),ET(36)
      WRITE(3,41)X(37),Y(37),R(37),AV(37),ET(37)
      WRITE(3,42)X(38),Y(38),R(38),AV(38),ET(38)
      WRITE(3,43)X(39),Y(39),R(39),AV(39),ET(39)
      WRITE(3,44)X(40),Y(40),R(40),AV(40),ET(40)
33    FORMAT(' DURA-KADMIYA          ',5(F9.6,4X))
34    FORMAT(' DURA-YARMUOK          ',5(F9.6,4X))
35    FORMAT(' KADMIYA-TAJI          ',5(F9.6,4X))
36    FORMAT(' YARMOUK-TAJI          ',5(F9.6,4X))
37    FORMAT(' TAJI-GHAZALI          ',5(F9.6,4X))
38    FORMAT(' TAJI-WAZIRIYA         ',5(F9.6,4X))
39    FORMAT(' N.BAGHD.-QUSAIBA 1    ',5(F9.6,4X))
40    FORMAT(' N.BAGHD.-QUSAIBA 2    ',5(F9.6,4X))
41    FORMAT(' N.BAGHD.-GHAZALI      ',5(F9.6,4X))
42    FORMAT(' N.BAGHD.-WAZIRIYA     ',5(F9.6,4X))
43    FORMAT(' N.BAGHD.-S.BAGHD.1    ',5(F9.6,4X))
44    FORMAT(' N.BAGHD.-S.BAGHD.2    ',5(F9.6,4X))
      CFPH=4.
      IF(ADOFH-6.) 200,200,201
201   WRITE(3,33)
      WRITE(3,500)
      OFNDS=SFNDS+CFNDS
      OFNDN=SFNDN+CFNDN+WOFDN
      CLL=40.
      ADOFH=2.
      DN=OFNDN/(AITLL*OP*CLL*(1.-SK))
      DP=OFNDS/((AITLL*OP*CLL*SK)
      DAV=(DN*WNN/(S+WNN))+(DP*S/(S+WNN))
      DSS=DP
      WRITE(3,11)
      WRITE(3,12)
      WRITE(3,14)
      WRITE(3,55)
      WRITE(3,15)ADOFH,DN,DSS,DAV
      DO 205 I=1,28
      Y(I)=DSS*A(I)
      X(I)=DN*A(I)
      R(I)=DAV*A(I)
205   CONTINUE
      DO 206 I=41,52
      X(I)=DN*A(I)
      Y(I)=DSS*A(I)
      R(I)=DAV*A(I)
206   CONTINUE
       WRITE(3,500)
        WRITE(3,507)
       WRITE(3,5069)
5069  FORMAT(35X,' TABLE(4.17  ) ')
      WRITE(3,207)
207   FORMAT(15X,' IRAQ 132K.V.TRANSMISSION LINES RELIABILITY INDICIES
     1 ')
```

```
      WRITE(3,300) ADOFF
      DO 202 I=1,28
      AV(I)=ADOFF/(ADOFF+R(I))
      UAV(I)=1.-AV(I)
      ET(I)=UAV(I)*8760.
208   CONTINUE
      DO 202 I=41,52
      AV(I)=ADOFY/(ADOFY+R(I))
      UAV(I)=1.-AV(I)
      ET(I)=UAV(I)*8760.
202   CONTINUE
      WRITE(3,17)
      WRITE(3,171)
       WRITE(3,505)
      WRITE(3,18)X(1),Y(1),R(1),AV(1),ET(1)
      WRITE(3,19)X(2),Y(2),R(2),AV(2),ET(2)
      WRITE(3,20)X(3),Y(3),R(3),AV(3),ET(3)
      WRITE(3,21)X(4),Y(4),R(4),AV(4),ET(4)
      WRITE(3,22)X(5),Y(5),R(5),AV(5),ET(5)
      WRITE(3,24)X(7),Y(7),R(7),AV(7),ET(7)
      WRITE(3,26)X(9),Y(9),R(9),AV(9),ET(9)
      WRITE(3,27)X(10),Y(10),R(10),AV(10),ET(10)
      WRITE(3,28)X(11),Y(11),R(11),AV(11),ET(11)
      WRITE(3,29)X(12),Y(12),R(12),AV(12),ET(12)
      WRITE(3,30)X(13),Y(13),R(13),AV(13),ET(13)
      WRITE(3,31)X(14),Y(14),R(14),AV(14),ET(14)
      WRITE(3,60)X(15),Y(15),R(15),AV(15),ET(15)
      WRITE(3,61)X(16),Y(16),R(16),AV(16),ET(16)
      WRITE(3,63)X(18),Y(18),R(18),AV(18),ET(18)
      WRITE(3,64)X(19),Y(19),R(19),AV(19),ET(19)
      WRITE(3,65)X(20),Y(20),R(20),AV(20),ET(20)
      WRITE(3,66)X(21),Y(21),R(21),AV(21),ET(21)
      WRITE(3,67)X(22),Y(22),R(22),AV(22),ET(22)
      WRITE(3,68)X(23),Y(23),R(23),AV(23),ET(23)
      WRITE(3,69)X(24),Y(24),R(24),AV(24),ET(24)
      WRITE(3,70)X(25),Y(25),R(25),AV(25),ET(25)
      WRITE(3,71)X(26),Y(26),R(26),AV(26),ET(26)
      WRITE(3,72)X(27),Y(27),R(27),AV(27),ET(27)
      WRITE(3,80)X(41),Y(41),R(41),AV(41),ET(41)
      WRITE(3,81)X(42),Y(42),R(42),AV(42),ET(42)
      WRITE(3,82)X(43),Y(43),R(43),AV(43),ET(43)
      WRITE(3,83)X(44),Y(44),R(44),AV(44),ET(44)
      WRITE(3,84)X(45),Y(45),R(45),AV(45),ET(45)
      WRITE(3,85)X(46),Y(46),R(46),AV(46),ET(46)
      WRITE(3,86)X(47),Y(47),R(47),AV(47),ET(47)
      WRITE(3,87)X(48),Y(48),R(48),AV(48),ET(48)
      WRITE(3,88)X(49),Y(49),R(49),AV(49),ET(49)
      WRITE(3,90)X(51),Y(51),R(51),AV(51),ET(51)
      WRITE(3,91)X(52),Y(52),R(52),AV(52),ET(52)
       WRITE(3,500)
       WRITE(3,423)
423    FORMAT(////)
      ADOFH=ADOFH+4.
      IF(ADOFH-14.) 303,303,304
304   CALL EXIT
      END
```

FEATURES SUPPORTED

```
C        A P P E N D I X  ( B 10 )
C    CALCULATION OF RELIABILITY MEASURES FOR TWO PARALLEL LINES CONNECTING
C    NASSIRIYA-SHUAIBA SUB STATIONS USING MARKOV APPROACH AND THE FREQUEN C
C    AND DURATION METHOD
C    S= EXPECTED STORMY WEATHER DURATION (HOURS)
C    WNN= EXPECTED NORMAL WEATHER DURATION  (HOURS)
C    DP=STORMY WEATHER OUTAGE RATE/YEAR
C    DW=NORMAL WEATHER OUTAGE RATE/YEAR
C    DAV=AVERAGE LINE FAILURE RATE
C    R1,2= MEAN REPAIR TIME (HOURS)
C    DAVAM= EQUIVALENT OUTAGE RATE USING APPROXIMATE METHOD
C    DAVE = EQUIVALENT OUTAGE RATE USING MARKOV EXACT METHOD
C    TAFF=MEAN TIME TO FAILURE USING APPROXIMAT METHOD
C    TTFF=MEAN TIME TO FAILURE USING THE MARKOV APPROACH
      DIMENSION A(6,6),AA(36),B(6,6),L(6),M(6)
      DATA A/36*0./
      WRITE(3,400)
400   FORMAT(50X,' NASSRIYA-SHUAIBA ')
      IC=0
      WNN=650.
      S=1.5
      SR=S/(S+WNN)
      DP=2./(5.*SR)
      DW=0.5/(1.-SR)
      WRITE(3,404)
404   FORMAT(50X,' ----------------------')
      DAV=(DW*(1.-SR))+(DP*SR)
      WRITE(3,401) DW
401   FORMAT(18X,'NORMAL WEATHER OUTAGE RATE /YEAR = ',E14.6)
      WRITE(3,402) DP
402   FORMAT(18X,' STORMY WEATHER OUTAGE RATE/YEAR = ',E14.6)
      WRITE(3,403) DAV
403   FORMAT(18X,' AVERAGE FAILURE RATE/YEAR= ',E14.6)
      WN=8760.0/WNN
      WM=8760.0/S
      MM=3
      WRITE(3,100)
100    FORMAT(2X,' STORMY WEATHE     DURATION OF          EQUIVALENT FAILU
     1RE RATE                    CYCLE TIME ')
      WRITE(3,101)
101   FORMAT(2X,' FAILURES  (     REPAIR (HR)    USING APP. METHOD
     1USING MARKOV TEQ.     APP. METHOD     MARK.TEQ ')
      WRITE(3,21)
21    FORMAT(19X,'-----------------------------------------------------------
     ------------------------------' )
10    READ(2,11) R1
11    FORMAT(F3.2)
      R2=R1
      U1=8760.0/R1
      U2=8760.0/R2
      SK=0.
```

```
14      DS=SK*DAV
        DN=DAV-DS
        DP1=(DS*(S+WNN))/S
        DP2=DP1
        D1=(DN*(S+WNN))/WNN
        D2=D1
        WNNY=WNN/8760.
         SY=S/8760.
         RY1=R1/8760.
        RY2=RY1
        X=WNNY/(WNNY+SY)
         XX=D1*D2*(RY1+RY2)
         XXX=SY*(D1*DP1*RY1+D2*DP1*RY1)/WNNY
          XY=SY*(DP1*D2*RY1+DP2*D1*RY2)/WNNY
         XYY=2.*DP1*DP2*(SY**2.)/WNNY
         DAVAM=X*(XX+XXX+XY+XYY)
         TATAM=1./DAVAM
        A(1,1)=D1+D2+WN
        A(1,2)=-D2
        A(1,3)=-D1
        A(1,4)=-WN
        A(2,1)=-U2
        A(2,2)=U1+WN+D1
        A(2,5)=-WN
        A(3,1)=-U1
        A(3,3)=U1+D2+WN
        A(3,6)=-WN
        A(4,1)=-WM
        A(4,4)=DP1+DP2+WM
        A(4,5)=-DP2
        A(4,6)=-DP1
        A(5,2)=-WM
        A(5,5)=DP1+WM
        A(6,3)=-WM
        A(6,6)=DP2+WM
        N=6
        K=1
        DO 2 J=1,6
        DO 2 I=1,6
        AA(K)=A(I,J)
        K=K+1
2       CONTINUE
        CALL MINV(AA,N,DD,L,M)
        K=1
        DO 20 J=1,6
        DO 20 I=1,6
        B(I,J)=AA(K)
        K=K+1
        CONTINUE
```

```
C        A P P E N D I X  ( C 1 )
C       THE RELIABILITY STUDIES OF THE RING SYSTEM SWITCHGEAR ARRANGEMENT
C         USING THE DEVELOPED GENERAL FORMULA
C       R(I) = CALCULATED RELIABILITY OF THE INDIVIDUAL FEEDERS
C       RAB= ELEMENTS RELIABILITY
C       TOOT= EXPECTED YEARLY OUTAGE TIME IN & HOURS &
        DIMENSION R(1000)
        IC=0
          N=4
10      READ(2,20)RAB
20      FORMAT(F8.6)
        RAS=RAB**3.0
        WRITE(3,200)
200     FORMAT('I   FEEDER  I  ELEM.RELIAB.  I  FEED.RELIAB.  I  E.P.OUT.
       1TIME/Y  I ')
        WRITE(3,55)
55      FORMAT(' ---------- ---------- ---------- ----------')
        DO  40 M=1,7
        DO 45 I=1,M
        K=M+1-I
        L=M-1
        R(I)=RAS**I+RAS**K-RAS**L
        TOOT=8760.0*(1.0-R(I))
        WRITE(3,42) I,RAB,R(I),TOOT
42      FORMAT(' I',4X,I3,5X,' I',2X,F12.6,2X,' I',2X,F12.6,2X,' I',3X,F12
       1.6,3X,' I')
45      CONTINUE
40      CONTINUE
        IC=IC+1
        IF(IC-N)10,35,35
35      CALL EXIT
COMPILATION DISCONTINUED

* 14 SYSTEM PROGRAM DETECTED MONITOR CONTROL RECORD
```

اما القسم الثالث فيشمل عرض وتحليل الاساليب والطرق المتبعة لايجاد درجة الثقة في شبكات التوزيع البسيطة والمعقدة مع تحليل بسيط عن كيفية ايجاد درجة الثقة • للمنظومات الكهربائية البسيطة من اخرى معقدة باستعمال طريقة قصر الدورة • كما يشمل البحث دراسة خواص منظومة الحلقة المستخدمة حاليا على نطاق واسع في التوزيع واستنتاج معادلة عامة لايجاد درجة الوثوق في مغذيات القدرة الخارجة بواسطة تطبيق نظرية الاحتمالات والرياضيات المعاصرة ، كذلك تطبيق هذه المعادلة وتهذيبها بحيث اصبحت معادلة عامة تشمل ايجاد حلول لعدة منظومات اخرى مستعملة في الحياة العملية بصورة اوسع •

الثاني فيحتوى على تحليل احصائي للحوادث والاخطاء التي وقعت على خطوط النقل الكهربائية ذات الضغط العالي ١٣٢ كيلوفولت ومعدات التحويل الثانوية المشمولة بهذا الضغط في كافة مناطق العراق للفترة (١٩٦٩ ـ ١٩٧٣) مع عرض للاسباب وقوع هذه الاخطاء وتخمين معدلاتها السنوية في الضروف الجوية الطبيعية وغير الطبيعية للاجهزة والخطوط وكذلك ايجاد العلاقات بين الظواهر الجوية وتأثيرها على هذه الاخطاء باستخدام الاساليب المتبعة في علم الاحصاء مع تفسير لبعض الملاحظات والنتائج التي استنتجت من قبل الباحث · وفي هذا المجال تجدر الاشارة الى الاقتراحات الواردة في هذه الدراسة الى ان الاسلوب الحالي المتبع حاليا في تحليل الحوادث والاخطاء وحفظ التقارير غير ملائم لاجراء دراسات وبحوث مستندة على حقائق عملية وذات اسلوب علمي ولهذا يؤكد الباحث على اهمية تسجيل الاخطاء والحوادث على نماذج معينة لغرض ضمان دقة المعلومات وشموليتها وبالتالي للاستفادة منها في الاغراض العلمية ·

ويشمل الفصل الثاني من هذا القسم ايضا تطبيق طريقة (ماركوف) المضبوطة على خط ناصرية ـ شعيبة الذي يعتبر الخط المثالي في العراق لاجراء البحوث كونه مارا باراضي مختلفة البيئة ويعاني من التقلبات الجوية كالعواصف الرعدية والترابية وتغيير الرطوبة وغيرها ، وكذلك اختبار هذه الطريقة بالطريقة التقريبية المبنية على الاسلوب الطوري · وقد استخدمت طريقة ماركوف في هذا البحث لتحليل تأثير تغير معدل الخطأ ومعدل الاصلاح على الخطوط الثنائية المحمولة على نفس البرج ومدى تأثير وضع هذه الخطوط على برجين منفصلين في نفس المنطقة ·

الخلاصـــة

الهدف الرئيسي لهذا البحث هو دراسة وتطبيق النظريات الحديثـــة التي ادخلت مؤخرا لغرض تحديد درجـة الثقة في انظمة القوى الكهربائيـة المصممة والموجودة مسبقا باقسامها الرئيسية الثلاث : التوليد ، النقـــل والتوزيع . وتطوير هذه الشبكات لتغطية التوسعات وازدياد الاحمال الكهربائية لمسايرة خطط التطوير الوطنية لغرض تأمين مصادر قدرة وشبكات موثوق بهـــا ولتقليل احتمال حدوث الانقطاعات وفشل تجهيز الطاقة لمستخدميها .

ينقسم البحث مبدئيا الى ثلاث اقسام رئيسية ، حيث يغطي القســـم الاول تحليل شامل لنظريات الثقة في انظمة توليد القدرة الكهربائية وتطبيـق هذه النظريات على محطات التوليد الموجودة حاليا في العراق بانواعهـــا المختلفة ، ودراسة تغيير الاحمال على هذه المحطات سنويا مع تخمين الاحمال المتوقعة في المستقبل باستعمال بيانات القيمة القصوى للحمل من سنة ١٩٦٠ الى ١٩٧٢ وذلك باستخدام طريقة متعدد الحدود المتعامدة التي تمثـل التغيير الطبيعي للقيمة القصوى على مدار السنة واستنتج منها التطور الطبيعـي للقيمة القصوى للسنوات ١٩٧٣ ـ ١٩٨٥ . وعلى ضوء هذه الدراسة امكـن دراسة احتياجات وتوسعات هذا القطر من اجهزة التوليد وحجومها لغايـــة سنـة ١٩٩٠ على ضوء ضمان الثقة في التوليد فقط ولم يتطرق الباحث الـــى الناحية الاقتصادية البحتة .

اما القسم الثاني من هذا البحث والذي يشمل دراسة وتطبيق نظريـــات الثقة المتعلقة بانظمة النقل فيكون من فصلين ، الفصل الاول يحتوي على عرض مفصل لاساليب والطرق والنظريات المستخدمة في هذا المجال ، اما الفصـل